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ABSTRACT

This study tested whether mental rotation performance of 186 high school students (80 males and 106 females) in grades 9 through 12 in art and nonart classes on Vandenberg's Mental Rotations test (S. Vandenberg and Kuse, 1978) was affected by gender, visual-spatial activities, strategies used while performing the test, and the ease of test taking. The major findings were: (1) males outperformed females; (2) students scored higher if they participated in visual-spatial activities in their past; (3) specific strategies yielded higher test scores, such as the mental rotation of the whole figure, and not just a section of the figure; and (4) as the Mental Rotations Test scores improved, the perceived ease of taking the test increased. No significant relationships were found between test scores and art ability, body movement strategy, visual-spatial activities performed in the present, or reported best academic subject. An appendix describes the pilot study. (Contains 11 tables and 131 references.) (Author/SLD)

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HIGH SCHOOL STUDENTS' PERFORMANCE ON VANDENBERG'S MENTAL ROTATIONS TEST: ART ABILITY, GENDER, ACTIVITIES, ACADEMIC PERFORMANCE, STRATEGIES, AND EASE OF TAKING THE TEST

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SUBMITTED IN PARTIAL FULFILLMENT OF THE DEGREE

MASTER OF ARTS IN ART EDUCATION

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NEW ROCHELLE, NY

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Abstract

The study tested whether mental rotation performance of 186 high school students (80 males, 106 females) in grades 9-12 in art and non-art classes on Vandenberg's Mental Rotations test (Vandenberg and Kuse, 1978) was affected by gender, visual-spatial activities, strategies used while performing the test, and the ease of test taking. The major findings were: 1) Males outperformed females, $t(184) = 6.184$, $p < .001$. 2) Students scored higher if they participated in visual-spatial activities in their past, $r(173) = +.221$, $p = .003$. 3) Specific strategies yielded higher test scores, such as the mental rotation of the whole figure not a section of the figure $F(4, 176) = 8.28$, $p < .001$, and using a visual instead of a verbal approach, $F(2, 178) = 11.697$, $p < .001$. 4) As the MRT scores improved, the perceived ease of taking the test increased. No significant relationships were between test scores and art ability, body movement strategy, visual-spatial activities performed in the present, or reported best academic subject.

Title: High School Students' Performance on Vandenberg's Mental Rotations Test

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I. INTRODUCTION

PURPOSE

The purpose of this chapter is to introduce the thesis study.

STATEMENT OF PROBLEM (RESEARCH QUESTION)

The question under study was: Is the mental rotation performance of high school students in art and non-art classes on Vandenberg's Mental Rotations Test (Vandenberg and Kuse, 1978) affected by art ability, gender, academic performance, visual-spatial activities, strategies used while performing the test, and the ease of taking the test? This research consisted of a retrospective causal-comparative design as well as a quantitative, descriptive survey questionnaire.

AREA OF INTEREST

As a sculptor and jeweler I have a strong interest in spatial ability because I can easily visualize in my mind the artwork I want to construct. Thinking three-dimensionally for me is an innate skill I possess that has become stronger over time. As I grew up, I realized that other people could not envision what I saw or solve three-dimensional problems in the same way I could.

I felt that if art teachers could know the innate level of spatial ability of a student, they could provide instruction in it and possibly raise it in a student with low spatial skills. If this could be done, others may be able to understand and enjoy my passion to create three-dimensional art. Creating art has given me a higher level of self-esteem and self-confidence.

As a teacher I have seen students who were not doing well academically, excel in art. It may have been based on an innate ability they had. They reported feeling good about their accomplishments.

As a teacher it is important to find out what you can do to help your students succeed. I believe that all students can succeed in creating art, no matter how much or how little innate talent they possess. This research study was a result of trying to see if students producing sculpture, like me, were high spatializers, and what characteristics did they have or what visual-spatial activities did they perform that may have influenced them to possess this skill. I also wanted to find out if spatial skills were important for success in other areas of study. I hoped that this study would provide an understanding about how to begin to develop a curriculum to stimulate spatial ability, so all students might have an equal opportunity to succeed in art or in whatever career they choose.

THEORITICAL ORIENTATION

This thesis acknowledges Howard Gardner's Theory of Multiple Intelligences (Gardner, 1993), stating we are all born with seven intelligences; some are more developed than others. Gardner (1993), defines intelligence as

> the ability to solve problems or to fashion products that are of consequence in a particular cultural setting or community. The problem solving skill allows one to approach a situation in which a goal is to be obtained and to locate the appropriate route to that goal. The creation of a *cultural* product is crucial to such functions as capturing and transmitting knowledge or expressing one's views or feelings. (p. 15)

They are Logical-Mathematical Intelligence, Linguistic Intelligence, Musical Intelligence, Bodily-Kinesthetic Intelligence, Interpersonal Intelligence, Intrapersonal Intelligence, Spatial Intelligence, "the ability to form a mental model of a spatial world and to be able to maneuver and operate using that model" (Gardner, 1993, p. 9). He discovered an eighth intelligence, the Naturalist Intelligence (Checkley, 1997).

The Intelligences might enable us to process information in different ways. If educational systems only focus on the traditional intelligences, logical-mathematical and linguistic) to measure the academic success of their students, those students who are gifted in one or more of the other intelligences might not be graded fairly or recognized as intelligent. They may even be thought of as poor learners. Therefore, teachers may need to teach to as many of the different intelligences as they can in order to have optimal learning and account for different learning styles.

BRIEF SYNOPISIS OF MAJOR CONTRIBUTIONS FROM LITERATURE

Spatial ability is a cognitive function that is broken into many components, such as spatial visualization and spatial orientation. However, researchers disagree on its definition. This study addressed spatial visualization using the following definition: "Spatial visualization is the ability to mentally rotate, manipulate, and twist two- and three- dimensional stimulus objects" (McGee, 1979, p.909). Shepard and Meltzer (1971), studied an aspect of spatial ability, mental rotations, in the hopes of defining it. They called it "mental rotations" because they hypothesized it was the cognitive process required to perform the task. It is the ability to mentally rotate an object in space. Vandenberg and Kuse (1978), developed a spatial ability test, the Mental Rotations Test (MRT) based on the findings of Shepard and Meltzer (1971).

Much research has been done on mental rotations, but it has been centered on the prediction, instruction, and the success of engineering students and people in the fields of mathematics, and physical science (Baker, 1990; Holliday-Darr, 2000; McGee, 1979; Ghiselli, 1966; Eliot and Smith 1983). Many tests have been developed to assess for mental rotations (Guay, 1977; Shepard and Meltzer, 1971; Vandenberg and Kuse, 1978; Gittler and Gluek, 1998; Seddon and Shubber, 1985). Spatial ability is an essential skill utilized in all of these fields, including fields

associated with art (Ascher, 1999-2000; Olsen, Eliot, and Hardy, 1998). It may lead to higher levels of critical thinking, which is an important skill all people should learn.

Spatial ability may be able to be taught, which has been demonstrated by research (Baker, 1990; Sorby, 1999; Holliday-Darr, 2000; Orde 1997; Seddon and Shubber, 1985). Giving a spatial ability test at the beginning of the school year may be useful for both the teacher and the student.

Research is pointing to even more reasons to increase spatial ability in women (Sorby, 1999; Holliday-Darr, 2000; Baker, 1990). Men typically score higher than women on mental rotation tests (Baker, 1990; Kimura 1999; Masters, 1998; Masters and Sanders, 1993; Peters, Laeng, Latham, Jackson, Zaiyouna, and Richardson, 1995; Resnick, 1993). Few women are found in the fields of engineering or other spatial related careers because they may not have chosen modes of spatial thinking as children, such as playing with three-dimensional building toys and blocks (Baker, 1990; Peters et. al, 1995). Therefore, there is a strong need to test for and implement a spatial ability curriculum starting at the elementary level.

PURPOSE OF THE STUDY

The purpose of this research was to study a subset of spatial ability called spatial visualization. It focused on the mental rotation performance of high school students in art and non-art classes on Vandenberg's Mental Rotations Test in respect to art ability, gender, academic performance, visual-spatial activities, strategies used while performing the test, and the ease of taking the test. The results supported past research on mental rotation ability, which has been studied with art and non-art students, gender differences, strategies used while performing the test, and academic performance. It also contributed additional information that may lead to

more studies in the area of mental rotation ability, such as information about the profile of high spatializers, strategies used while performing the test, and how students view the ease of the test.

RESEARCH DESIGN

The research design was divided into two parts. First, a retrospective causal-comparative study compared the mental rotation ability, a subset of spatial ability, to five different types of classes of high school students, comprised of art and non-art students, to see which class type had the highest test scores on Vandenberg's Mental Rotations Test (Vandenberg & Kuse, 1978). The effect was the score of the spatial ability test; the cause investigated was the spatial ability to perform mental rotations. The second part of the study used a quantitative, descriptive research design in the form of a survey, a questionnaire. It supplied information to compare the mental rotations test to gender, academic performance, visual-spatial activities, test-taking strategies used while performing the test, and the ease of taking the test.

ASSUMPTIONS

An important aspect of this study assumes that each individual has spatial ability. Some individuals may have more or less than others, but everyone uses some level of spatial ability. I can only assume that spatial ability exists because people naturally function in a three-dimensional environment.

I assumed that intelligence level and abilities in math and science were related to spatial ability.

GLOSSARY OF TERMS

SPATIAL ABILILTY

The study investigated a subset of spatial ability, spatial visualization. Researchers do not agree on the definition of spatial visualization, as discussed previously. This study was based on

the following definition: "Spatial visualization is the ability to mentally rotate, manipulate, and twist two- and three- dimensional stimulus objects" (McGee, 1979, p.909).

STRATEGY

Strategy is defined as the "Retrospective, self-reported psychological technique, method, or approach employed by a participant as a means to solve the problems on the Mental Rotations Test" (Moody, 1998, p. 10).

HYPOTHESES

Hypothesis 1: Art and Non-Art Classes

Art classes score higher on the MRT than non-art classes.

Hypothesis 2: Comparison of Class Types

The following hypotheses compare MRT performance and class type:

a. Sculpture classes have significantly higher scores on the MRT than Drawing and Painting classes.

b. Drawing and Painting classes have significantly higher scores on the MRT than Studio Art Foundation classes.

c. Studio Art Foundation classes have significantly higher scores on the MRT than the Social Studies class and Psychology classes.

Hypothesis 3: Gender

Males score significantly higher on the MRT than females.

Hypothesis 4: Visual-Spatial Activities

a. Students who score high on the MRT also score high on the items in "In the Past" part of *Section 2* of the questionnaire. There is a positive correlation between the MRT scores and activities students did in the past.

b. Males who score high on the MRT also score high on the items in "In the Past" part of *Section 2* of the questionnaire. There is a positive correlation between the MRT scores and activities males did in the past.

c. Students who score high on the MRT also score high on the items in the "Now" part of *Section 2* of the questionnaire. There is a positive correlation between the MRT scores and activities students are doing now.

Hypothesis 5: Strong Academic Performance per Discipline

Students whose state their best academic subject (written either numerically or with a letter grade) in school this year, is in art, math, or science score higher on the MRT than those students whose best grade is in English or Social Studies.

Hypothesis 6: Ease of Taking the Test

There is a positive correlation between a student's MRT score and the ease of taking the test.

Hypothesis 7: Strategies Used to Solve Problems

<u>Mental Rotation Strategy:</u>

a. Students who mentally rotate the whole figure score significantly higher on the MRT than students who rotate a section of the figure.

b. More males than females mentally rotate the whole figure to solve the problems on the MRT.

Visual and Verbal Strategy:

c. Students who use a nonverbal, visual approach (abstract, mental images), score higher on the MRT than students who think through the steps verbally in their mind.

d. More males than females use a nonverbal strategy to solve the problems on the MRT. Females use a verbal strategy more than males.

Use of Body Movements Strategy:

e. Students who do not use movements of their fingers, hand, and/or pencil to help solve the problems on the MRT score higher than students who use movements of their fingers, hand, and/or pencil to help solve the problems on the MRT.

f. More females than males use movements of their fingers, hand, and/or pencil to help solve the problems on the MRT.

Independent Variables: Different levels of spatial ability in the following groups: art and non-art students, gender, academic performance, outside activities, strategies of taking the test, and the ease of taking the test.

Dependent Variable: Level of spatial ability, the scores on Vandenberg's Mental Rotation Test.

II. REVIEW & CRITIQUE OF RELATED RESEARCH LITERATURE

PURPOSE

The purpose of this section is to review the literature related to the research study.

RESEARCH QUESTION

Is the mental rotation performance of high school students in art and non-art classes on Vandenberg's Mental Rotations test affected by art ability, gender, academic performance, visual-spatial activities, strategies used while performing the test, and the ease of taking the test?

KEY TERMS

Art Education

Art Education and 3D art

3D Art

Spatial Ability

Spatial Ability and Engineering

Mental Rotations

Visual Perception

Visual Acuity

"Three-dimensional Ability" Testing

Innate Ability

Spatial Relations

Spatial Orientation

Spatial Visualization

Perception

CRITERA FOR SELECTION OF LITERATURE

1. The literature is in English.
2. It is dated 1938 or later.
3. It is found in a peer- review journal.
4. It is related to areas of spatial ability.
5. It is on the topic of mental rotations.
6. It can discuss the theories on spatial ability and a subset of it, mental rotations.
7. It can be on the topic of mental rotations and cognition.

ARTICLE REVIEWS, GROUPED UNDER TOPICS

Eighteen articles are divided into three categories: *Spatial Ability Defined and Its Importance in Education*, *Spatial Ability Testing*, and *Instruction to Increase Spatial Ability*. In order to study and understand spatial ability it needed to be defined. Once it was defined, studies have been conducted, using tests to find the level of spatial skills an individual possesses. Because educators believe spatial ability is an important cognitive skill, studies in instruction to increase this skill have been performed. This section describes these findings.

SPATIAL ABILITY DEFINED AND ITS IMPORTANCE IN EDUCATION

Roberts Braden (1993), Department of Communication at Chico State University, Chico, discussed what is visual literacy and how can we define it. His purpose was to review the topic of visual literacy over the past twenty-five years, define it, explain the reasons for its importance, and discuss areas that need to be researched. He discussed various viewpoints on visual literacy, visual thinking, visualization, and visual learning. There has been much disagreement about the concept of visual literacy. Arnheim (1969), was the first to coin the phrase visual thinking (Braden, 1993, p. 6). (Debes, 1969), has given the longest lasting definition:

> Visual literacy refers to a group of vision competencies a human being can develop by seeing at the same time he has and integrates other sensory experiences. The development of these competencies is fundamental to normal human learning. When developed, they enable a visually literate person to discriminate and interpret the visible actions, objects, and/or symbols, natural or man made, that he encounters in his environment. Through the appreciative use of these competencies, he is able to comprehend and enjoy the masterworks of visual communication. (Debes, 1969, p. 14 cited in Braden, 1993, p. 1)

According to Horton (1980, p. 169), "Visual literacy is the ability to understand and use images, including the ability to think, learn, and express oneself in terms of images" (cited in Braden, 1993, p. 2). "Visual literacy can be explained in terms of being able to use visuals for communication, thinking, learning, constructing meaning, creative expression, and aesthetic enjoyment" (Baca, 1990, p. 65 cited in Braden, 1993, p. 3). The visual literacy movement has always been tied to the field of education, where images have been utilized for instructional purposes. Dwyer (1987, 1984, 1972), has performed ongoing experimental research. The first phase of his research in 1972, known as the Program of Systematic Evaluation (PSE) was developed from his *Guide for Improving Visualized Instruction*. He continued through two more phases and over two hundred PSE experiments. "The findings of PSE have resulted in dozens of principles for visualized instruction and for visual design" (Braden, 1993, p. 5). Visuals strengthen retention and provide better assessment. According to much research, learning is more effective if both visuals and verbal materials are used, rather then each of them independently (Appelbaum 1993; Dwyer, 1988; Fleming, 1987; Braden 1983; Duchastel, 1978; cited in Braden, 1993, p. 7).

Much research still needs to be done on visual literacy in order to understand its impact on cognitive learning and assessment. According to Baca (1990),

> Visual literacy research is needed to identify the learnable visual literacy skills, is needed to identify the teachable visual literacy skills, is needed to develop implementation of visual literacy constructs, is needed to validate implementation of visual literacy constructs, is needed to provide a rationale for visual literacy implementation in our society, is needed to provide a rationale for visual literacy implementation in our educational system, is supplemented by research conducted in other fields, included psychology, education, learning, visual perception and eye movements studies, print literacy (Baca, 1990, p. 70 cited in Braden, 1993, pp. 7-8)

Braden suggests that visual images are a necessary part of learning. Without visual literacy, spatial ability might be extremely difficult, if not impossible, to learn because instruction in spatial ability requires visual images.

Amy Brualdi (1996), at the Educational Resources Information Center discussed Howard Gardner's definition of intelligence, the origins of Gardner's theory of seven multiple intelligences, how it is used in the classroom, and its role in assessment. Gardner defines intelligence as "the capacity to solve problems or to fashion products that are valued in one or more cultural setting" (Gardner and Hatch, 1989 in Brualdi, 1996, p. 1). Gardner believes that multiple intelligences are the result of both biological and cultural influences. "Various types of learning results in the synaptic connections in different areas of the brain" and different cultures provide the motivation to develop certain types of intelligences (Brualdi, 1996, p. 3).

Gardner does not believe in the two traditional intelligences, verbal and computational (mathematical). He hypothesizes that there are seven intelligences: Logical-Mathematical

Intelligence, associated with mathematic and scientific thought; Linguistic Intelligence, the ability to understand language; Spatial Intelligence, "the ability to manipulate and create mental images in order to solve problems" (Brualdi, 1996, p. 2); Musical Intelligence, the ability to recognize and compose musical pitches, tones, and rhythms; Bodily-Kinesthetic Intelligence, using one's mental ability to understand the placement of one's body in space; and the Personal Intelligences, both interpersonal, understanding the feelings of others and intrapersonal, understanding oneself (Brualdi, 1996).

Gardner's theory states we are born with all seven of these intelligences, but some are more developed than others. They enable us to learn in different ways to process information. If educational systems only focus on the traditional intelligences to measure the success of their students, those students who are gifted in one or more of the other intelligences will not be graded fairly or recognized as intelligent. They may even be thought of as poor learners. Therefore, teachers need to teach to as many of the different intelligences as they can in a lesson in order to have optimal learning of the lesson and account for different learning styles. For children to learn and assess information, they need to be given the opportunity to express their ideas using different intelligences to successfully participate in classroom learning (Brualdi, 1996, p. 5).

Folkert Haanstra (1996), at the University of Amsterdam, The Netherlands, discussed the effects art education has on visual-spatial ability and aesthetic perception by using a statistical procedure of meta-analysis in a quantitative review based on his doctoral dissertation. His purpose was to examine the effects of art education on visual-spatial ability and aesthetic perception. Visual-spatial ability was "defined as a set of related capacities to process (search,

encode, remember, match, transform) visual-spatial information (forms, shapes, positions)" (Carroll, 1993 cited in Haanstra, 1996, p. 197). Haanstra's definition stated:

> Visual-spatial ability is a psychological concept derived from the psychometric approach to human performance. It can be described as a skillful set of responses to spatial tasks, such a reading a map or blue print, estimating the length of a string needed to tie a parcel, or imagining how a room will look after re-arranging the furniture. (Haanstra, 1996, p. 198)

Eliot (1987), and Lohman (1988), defined two types of spatial tasks: recognition tasks, "the perception, retention, and transformation of visual forms within a two-dimensional plane" and "manipulation tasks, the mental transformations of visual shapes across a plane, such as rotating, folding, or transposing" (cited in Haanstra, 1996, p. 198).

The meta-analysis, comprised of 30 studies on visual-spatial ability and 39 studies on aesthetic perception, was based on some experimental designs, but mostly quasi-experimental designs with studies examining lessons on instruction in studio art, art criticism art history, aesthetics, or a combination of studio art and the study of art works, studies involving assessments of effects on visual-spatial ability or aesthetic-perception, and studies reviewed between 1960 and 1990 (Haanstra, 1996, pp. 200-201). Statistical analysis stated,

> The average effect size (*d*) of the studies on visual-spatial ability is 0.21. This means that art education in the collected studies leads to an average of 0.21 standard deviation improvement in scores on visual-spatial tests. As the 90% confidence interval around the average effect size encompasses zero one cannot conclude that there is a significant effect across studies. The average education effect on aesthetic perception is 0.53…one may conclude that there is a significant effect across studies. (Haanstra, 1996, p. 201)

The statistical analysis results of this meta-analysis showed that art education did not affect visual-spatial ability, but it did increase aesthetic perception. According to Haanstra (1996), more research should be done on the, "evaluation of different types of integrating theoretical and hands-on instruction" (p. 207). In order to develop aesthetic perception, art education needs to study art works and have studio instruction. (Haanstra, 1996, p. 207). Although there are many tests for spatial ability, they are in need of refinement to better test for spatial ability. Future research is needed to further understand the spatial operations used in art (Haanstra, 1996, p. 207).

Bedrich Lubojacky (1999), USB- Technical University of Ostrava. Pavel Duzi, Comparative Orography Research, and Michaela Tercova (1999), University of Ostrava, discussed in this theoretical article if students entering an engineering program at a university or technical college might increase their space perception and space imagination by a computer program that focuses on using three-dimensional objects. Their purpose was to present ideas about space perception and space imagination for work in the field of technology such as engineering and the machine industry. Students may be weak in these perceptual skills. They may have had minimal exposure in art education, which allows for the manipulation of three dimensional objects either directly, physically working in a clay, wood, or metal, or indirectly, creating two dimensional drawings.

According to the authors, "man physically moves in space and perceives it by his developed sense organs" (Lubojacky, Duzi, and Tercova, 1999, p. 2). By physically manipulating and engaging in the physical space around you, you might be able to perceive spatial perception. Too much exposure to television, which is a flat two-dimensional media, may be a cause of poor space perception and space imagination because it is a secondary source, not witnessed first

hand. When you witness something first hand, you have a better memory retention of it. The stories on television are not real; we are removed from our emotions and our creativity to imagine stories. The authors proposed "we cannot experience it authentically, we cannot feel pain, weight, fear, we cannot experience danger on our own skin" (Lubojacky, Duzi, and Tercova, 1999, p. 2).

In primary and secondary schools space perception and space imagination might be enhanced by more art education classes, by examining space from multiple perspectives, such as map reading, and using models and visual aids where appropriate. This in turn will show as a positive reflection at the college level. Although the authors did not test this idea or provide references to back up their theories, more research and testing of their idea is needed.

Stanley S. Madeja (1997), Professor of Art at Northern Illinois University, DeKalb, Illinois, discussed the relationship between perception and the making of art. His purpose was to propose a model of the artistic process, which described the repertoire of perceptual clues that the artist develops and the importance of the relationship between perception and the making of art. He used this model to teach art criticism, art history and aesthetics (Madeja, 1997, p. 3). It described the process of how an artist creates a work of art from its inception to the finished piece. The paper was in two parts: the author's research and development activities in the Aesthetic Education Program and a description of the Model for the Artistic Process and its relationship to perception and instruction.

Madeja (1997), defined visual perception as "the ability of the artist to recognize and understand visual phenomena and aesthetic clues and is fundamental in creating and responding to works of art" (Madeja, 1997 p. 2). He categorized Arnheim's (1969) perceptual theory into five phases: observation- the act of noticing and perceiving, description of visual relationships,

selectivity, generalization of form, and abstraction (Madeja, 1997, pp. 3-4). Aesthetic perception is tied to the general perception theory (Madeja, 1997, p. 8). Arnheim (1969), tied aesthetic perception to the expressiveness of an object. "Expression is a constant phenomenon accompanying all perception and that it is the presence of expression that sets the arts apart as a unique phenomenon" (Madeja, 1997, p. 7). Madeja (1997), cited Goodman (1990), who tied aesthetic perception to general cognitive theory; Gibson (1950), who tried to relate aesthetic perception to his functional notion of perception; Sherman (1947, 1981), tied aesthetic perception to our physiological mechanisms for seeing; and Schaefer-Simmern (1981), considered aesthetic perception a basic to cognition (Madeja, 1997, p.8). Madeja (1997), developed a model for artistic process in which perception may play a formative role. The model is comprised of four parts: knowledge base in art, perception- how the artist perceives the world around him or her [based on Arnheim's (1993), theory of perception and its role in the visual concept formation], the making of the work of art- the product of what the artist has perceived, and the artist- his or her perceptual skills, knowledge, insight, aesthetic, and creative judgment (Madeja, 1997, p. 8). Another interesting theory on visual perception by Sandra Blakeslly (1993), focused on the biological functioning of the brain. An image in the mind's eye may actually be physically there (Madeja, 1997, p. 9).

Madeja (1997), believed that "Perception is a major player in the game of creating art. It is important to teaching all students, but particularly art students, how and what to see and how to analyze and make judgments as to what they see" (p. 14). Not only the end result of a finished work of art is important, but also the process of creating the work of art. Because all of the theorists mentioned above have different views on aesthetic perception, it is difficult to arrive at one general definition of it. Aesthetic perception is a subset of visual perception; visual

perception is analogous to spatial ability. You can visually perceive an object, but to fully understand its form and its relationship in space, spatial skills are a necessity.

Mark G. McGee, associated with Texas A & M University, set out to:

a) summarize psychometric studies of human spatial abilities, b) examine the arguments to the hypotheses that sex differences in various aspects of perceptual-cognitive functioning (Mathematics) are secondary consequence of differences with respect to spatial visualization and spatial orientation abilities, and c) review literature with reference to environmental, genetic, hormonal and neurological influences that interact in producing individual variation in spatial test scores. (McGee, 1979. p. 889).

Past research suggested the evidence of at least two spatial factors of spatial ability, Visualization and Orientation (French, 1951; Thurston, 1950; Guilford and Lacey, 1947; Ekstrom, French, and Harman, 1947 cited in McGee, 1979. p. 890). "Spatial visualization is the ability to mentally rotate, manipulate, and twist two- and three-dimensional stimulus objects" (McGee, 1979, p. 909). To have good visualization skills, you need to have two strong mental functions: imagery and mathematical ability. "Spatial manipulation involves imagery control and that imagery vividness and control may be related to individual differences in performance on tests of spatial ability" (McGee, 1979, p. 896). Spatial visualization is required in various perceptual-cognitive tasks involving the mental transformation of visual images and for success in mathematics. "Spatial orientation involves the comprehension of the arrangement of elements within a visual stimulus pattern, the aptitude to remain unconfused by the changing orientation in which a spatial configuration may be presented, and the ability to determine spatial orientation with respect to one's body" (McGee, 1979, p. 897). Spatial orientation may affect tasks of field dependence-field independence, sense of direction, map reading, and maze tasks.

Spatial ability may be assessed through spatial testing, which was used "for selecting workers for industrial jobs and predicting job performance" (Ghiselli, 1966, 1973 cited in McGee, 1979, p. 894) and "...for the prediction of success in vocational-technical training programs" (Smith, 1964 cited in McGee, 1979, p. 894).

Barbara J. Orde of Chadron State College discussed the relationship between drawing ability and spatial/visual perceptual ability and their potential implications for education and training by reviewing literature on spatial ability and drawing. She defined drawing, spatial, and visual-perceptual abilities, and their connection to information processing and intelligence. (Orde, 1997, p. 271).

Researchers have various definitions of spatial/visual perceptual ability. Goins (1958), defined visual perception as "the process by which phenomena are apprehended by the mind through the medium of the eye" (Goins, 1958, p. 1 cited in Orde, 1997, p. 275). Linn and Peterson (1985), defined spatial ability "as representing, transforming, generating, and recalling non-linguistic information" (Orde, 1997, p. 272). Many researches identified spatial ability in three main areas: "spatial relations, spatial orientation, and spatial visualization" (Rowe, 1991 cited in Orde, 1997, p. 272). Gardener (1988), defined them as specified in the Test of Visual-Perceptual Skills. They are:

> Visual discrimination [Spatial relations]. "A child's ability to remember for the immediate recall (after four or five seconds) all of the characteristics of a given form, and being able to find this from an array of similar forms.
>
> Visual-spatial relationships [Spatial orientation]. A child's ability to determine, from among five forms identical configuration, the one single form or part of a single form that is going in a different direction from the other forms.

> Visual form constancy [Spatial visualization]. A child's ability to see a form, and being able to find that form, even though the form may be smaller, larger, rotated, and/or hidden. (Gardener, 1988, p. 65 cited in Orde, 1997, p. 273).

Orde (1997), presented many positive implications for spatial ability in education. A cognitive operation occurs when the visual perception (spatial ability) is translated into a concrete product, a drawing (Gardner, 1982; Sherman, 1947 in Orde, 1997, p. 276). "By acknowledging relationship between drawing and spatial ability, we may more accurately design art education curricula to teach visual literacy and meet these learning needs of children" (Orde, 1997, p. 275). Because spatial ability and drawing can be trained (Cunningham and Reagan, 1972; Szeto, 1975; Sherman, 1947), and are related to each other, Orde (1997), believes art education curricula should be designed to teach visual literacy and meet these learning needs of children (Orde, 1997, p. 275). Visual–perception may become a trainable skill, which may be developed beyond what is considered the norm. (Orde, 1997, p. 271).

Eliot and Smith (1983), found a strong correlation between spatial ability and success in academic areas such as mathematics, interior design, physics, technical drawings, woodwork, and engineering because they require "analytical visual skills" (Orde, 1997, p. 273). "Eliot and Smith pointed out several positive correlations between spatial ability and a general art class (.404) and specific art-related skills such as technical drawing (.45), metal work (.475, mechanical science (.492), and woodworking (.67)" (Eliot and Smith, 1983, pp. 436, 442 cited in Orde, 1997, p. 273). Their spatial test results showed a "significant relationship between scores in these academic areas and spatial ability" (Eliot and Smith, 1983, n.p. cited in Orde, 1997, p. 274), which showed a correlation between spatial ability and intelligence. Therefore, spatial ability may be a necessary part of education and art education. "The development of perceptual

skills is an often stated goal of art education" (Orde, 1997, p. 275). It might also be a necessary skill in mental development (Messaris, 1994; Clark 1993; Clark and Wilson 1991; Shannon, 1991; Clark, 1989; Clark, Zimmereman and Zurmuehlen, 1987; Cook, 1985; Gardner, 1982; Cunningham and Reagan, 1972; Eisner, 1972; McFee, 1970; Tiebout and Meier, 1936 cited in Orde, 1997, p. 275). Art might help with developing higher level thinking skills (Feldhous, 1992 cited in Orde, 1997, p. 276).

Orde (1997), concluded that spatial ability may be necessary in fields that require three-dimensional thinking, such as engineering, mathematics, science, and design. In order to test these ideas research is needed to predict spatial ability and describe ways to nurture its growth in an individual. Developing spatial ability in students might become a goal in education and art education because "it is possible that we will find spatial ability to be similar in importance to such traits as verbal or social intelligence (Smith, 1965, p.100 cited in Orde, 1977, p. 276).

Sheryl A. Sorby of Michigan Technical University examined what is spatial ability or what this paper refers to as spatial skills, and what research has been done in this area. Her purpose was to provide an in depth examination of spatial skills: its definition, how to develop it, how to evaluate it, and if gender has an effect on it.

"Spatial ability is defined as the innate ability to visualize that a person has before any formal training has occurred, i.e., a person is born with a certain degree of spatial ability. However, spatial skills are learned or are acquired through training" (Sorby, 1999, p. 21). Because Sorby (1991), believed it is hard to judge if a person has learned this trait prior to post secondary education, she has used these two terms interchangeably.

There are many theories on spatial ability. McGee (1979), divided spatial ability into two categories: spatial visualization with Mental Rotation (the entire object is rotated in space) and

Mental Transformation (part of the object is transformed in some way) (Sorby, 1999, p. 22). Arnheim (1986), viewed spatial ability as a combination of two essential parts: "perception (visual thinking) and reasoning (cognitive thinking)". Arnheim (1986), believed, "Thinking, then, is mostly visual thinking" (in Sorby, 1999, p. 22). McKim (1980) and Sommer (1978), believed in the importance of visual thinking skills and visualization. Sommer (1978), believed "that our educational system is to blame for the lack of emphasis on visualization and visual thinking skills" (Sorby, 1999, p. 23).

According to Bishop (1978), Piaget (1956), believed spatial skills are developed in three stages: 1) Topological skills with ages 3-5, where children understand the closeness of objects to one another 2) Projective spatial ability, where children, by adolescence, can visualize three-dimensional objects and perceive what they look like from different angles or due to rotation or transformation in space. 3) By adulthood, combination of measurement concepts and projective skills, where people can visualize "area, translation, rotation and reflection" (in Sorby, 1999, p. 23). These ideas suggested that activities requiring hand-eye coordination may help develop spatial skills, such as playing with construction toys as a child, taking classes such as shop, drafting, or mechanics in school, playing three-dimensional computer games, playing in sports, and having good math skills (Sorby, 1999, p. 22).

Many tests have been developed to assess spatial ability: Minnesota Paper Form Board (MPFB) (Likert, 1970); Differential Aptitude Test: Space Relations (DAT:SR) for paper folding (Bennett et al., 1973); Purdue Spatial Visualization Test (PSVT-R) (Guay, 1977) for mental rotations; Mental Rotation Test(MRT) (Vandenberg and Kuse, 1978) "to assess a person's skill in visualizing rotated solids" (Sorby, 1999, p. 25) ; and 3-Dimensioanl Cube (3DC) for mental rotations (Gittler, 1998) (Sorby, 1999, pp. 24-26).

"The development or improvement of 3-D spatial visualization skills is often cited as one of the major goals of engineering design graphics education" (Sorby, 1999, p. 21). Research suggested the necessity of engineering students to acquire these skills. Women, who are enrolled in freshman design graphics courses, may drop out if they lack the spatial skills necessary to take the course (Sorby, 1999, p. 28). Computer lessons on teaching spatial skills and having students sketch hand-held models may enhance these skills (Sorby, 1999, pp. 28-29). McKim (1980) pointed out "that the ability to think is essential not only for artists but also for those in scientific and technical careers" (Sorby, 1999, pp. 26-27).

Andi Neustadter Stix , Ed.D., Teacher's College, Columbia University, New York, in 1992, wrote this doctoral thesis, researching her hypothesis that teaching mathematics with pictorial note-taking will decrease the anxiety level and increase the self-confidence of teachers-in-training (preservice teachers). Her purpose in this quasi-experimental study was to:

> create a multi-modal journal system with a linguistic, pictorial and numeric format; to design a training model that incorporated instructional procedures and journal-writing analysis; and to refine the model by field testing it at the college level with preservice teachers. (Stix, 1992, p. 42)

Convenience sampling formed 52 women students in a middle class, suburban, undergraduate teacher-training program in their junior or senior year at Pace University in White Plains, NY. However, the final sample consisted of 40 students because twelve did not do the homework or were absent on the day of the tests.

Two instruments, designed for this study, were a "self-rating test of personal feeling about mathematics in general and a test comparing the personal feelings about the use of the bimodal to the trimodal journal form" (Stix, 1992, p. 43). The self-rating test was administered three times:

the beginning of the study, week seven, and week twelve. Different types of math instruction on the same mathematical concept were given to a control group (n=26) and an experimental group (n=26). The control group, the bimodal group, was instructed with words and numbers to explain mathematical concepts up until the seventh week and was retested in the twelfth week after incorporating pictorial diagrams as well. They rated their use of the trimodal condition, which consisted of words, numbers, and pictures. The experimental group, trimodal group, was instructed with pictures, words, and numbers.

After the instruction, a posttest designed by the researcher, a five point Likert Scale (1=nonexistent, 2=marginal, 3=adequate, 4=above average, and 5=high) testing level of anxiety of teaching mathematics, self-confidence in mathematics, and perceived ability to teach math, was given to determine the learning levels between the groups. A qualitative study in the form of an essay question was administered in the twelfth week to the bimodal group, who were given the trimodal approach to learning at the seventh week, to express their feelings about both types of journal writing.

Sixteen questions from the two five-point Likert Scales on measuring attitudes on math anxiety levels and journal writing ability were used for analysis. "Results of the t-tests indicated that there were no significant between-group differences at midterm ($t(38)=-1.09$,n.s.) and no significant difference on the posttest ($t(38)=-0.44$,n.s.). For the bimodal group, there was a significant pretest to midterm difference ($t(19)= -5.34$, $p < .001$)." "For the trimodal group, there was a significant pretest to midterm difference ($t(19)= -4.49$, $p < .001$) (Stix, 1992, p. 48). There was a significant midterm to posttest difference ($t(19)= -6.19$, $p < .001$)." "All differences reflect a decrease in math anxiety" (Stix, 1992, p. 49). Results showed that the experimental group did better on the posttest. Also, results showed that pictorial note-taking decreased anxiety levels and

increased the self-confidence of teachers-in-training. The use of pictorial representation and a multi-modal instruction has shown to be effective by other researchers (Baum 1990; Ben-Chaim, Lappan, and Houang, 1989; Clements and Del Campo, 1989; Phillips, 1987).

Stix (1992), defined the global construct of visual-spatial ability into five groups: Visualization, the ability to recognize information without the manipulation of objects or operative thought (Dixon, 1983 cited in Stix, 1992, p. 107); Spatial ability, the ability to determine the relationship and patterns among objects; Visual-spatial ability (sometimes referred to as spatial ability), the combination of two functions, spatial orientation and spatial-visualization; Spatial Orientation; and Spatial Visualization. Spatial orientation is the ability to "mentally readjust perspective to become consistent with a representation of an object presented visually (Tartre, 1990, p. 217 cited in Stix, 1992, p. 15) and spatial visualization is the ability to mentally "manipulate, rotate, twist, or invert a pictorially presented stimulus object (McGee, 1979 cited in Stix, p. 16). Stix (1992), also defined spatial thinking when visualization and spatial ability come together "Spatial thinking occurs when visualization and rational thought are applied together"(Dixon, 1983, p. 56 cited in Stix, 1992, p. 12). Gardner (1983), "claimed that spatial intelligence is the capacity to perceive the visual world accurately, to change one's initial framing of a problem, and be able to reassemble one's visual experience, without external cues (Gardner, 1983 cited in Stix, 1992, pp. 12-14).

The results showed that pictorial note-taking decreased anxiety levels and increased the self-confidence of these teachers-in-training. Also, these preservice teachers were able to retain the information longer than the control group. The problems with the research are: convenience sampling, where only one college and a very small sample of subjects was used; threats to

internal validity: mortality, differential selection of participants, and selection-maturation interaction; and threats to external validity: selection-treatment interaction.

SPATIAL ABILITY TESTING

Elizabeth Ascher of Colgate University (1999-2000), compared "visuospatial abilities in terms of their relationship to gender and artistic ability/experience" (Ascher, 1999-2000, p. 150). In this causal-comparative research, she hypothesized:

> Artists, as a group, would perform better than non-artists and that within the non-artist group, males would perform at a higher level than females, whereas with the artist group, no such effect of gender would be found. It was also predicted that artists would show a left hemisphere advantage and non-artists would show a right hemisphere advantage in mental rotation abilities. (Ascher, 1999-2000, p. 150)

Stratified sampling formed two groups. In the artist group, referred to as "artists", (n=20: 10 men and 10 women), selected from the art departments of two undergraduate universities with comparable admissions standards and academic requirements, were undergraduates (n=18) and art professors (n=2). Prior to participation they indicated they were art majors and considered themselves artists. In the non-artist group, referred to as "non-artists", (n=20: 10 men and 10 women), four were enrolled in an introductory psychology class and received course credit for their participation, and the rest were volunteers. Prior to participation they indicated that they were not art majors and did not consider themselves artists. Both groups were further broken down into right-handed, non-right handed, right eye dominant, and left eye dominant, i.e. a person could be right handed and right eye dominant.

The instrument was a mental rotation task of eight practice trials and eighty test trials created by Render Boy software for a Macintosh desktop computer. In each trial of two grayscale-

shaded images of three-dimensional shapes, the first image was presented center on the screen and the second image was presented laterally, to the right or left side of the screen. An image was shown, then faded out, and another image appeared on the screen that was the same or different from the first image. The subjects had to choose "the same key" or "the different key" for each trial for the second image in the trial. Two computers with two separate keyboards displayed one trial at one time, forcing the subject to use different hands for "the same key" and "the different key" on each computer.

Accuracy and reaction time were given "repeated measures of analysis" with two levels each having "independent variables: artistic ability (artists and non-artists), sex (males and females), handedness (right and non-right), and eye dominance (right and left), with two levels of visual field (right and left)" (Ascher, 1999-2000, p. 151). Results showed:

> In terms of accuracy, the only significant effect was a main effect for sex, $F(1,25)=5.62$ $p<.05$, such that men ($M=11.55$, $SD=6.22$) made significantly fewer errors than women ($M=15.10$, $SD=5.44$). For reaction time, there was a marginally significant interaction between sex and eye dominance, $F(1,25)=4.03$, $p,<.057$. Independent sample t tests showed that right eye dominant males ($M=817.70$, $SD=145.18$) had significantly faster reaction times than left eye dominant males ($M=1010.17$,$SD=145.18$), $t(18)=2191$, $p<.01$. In females, although the opposite trend for eye dominance was shown, this difference was not significant. There was also a marginally significant three-way interaction between artistic ability, handedness, and eye dominance, $F(1,25)=3.99$, $p<.058$. In non-artists, there was a significant interaction between handedness and eye dominance, $F(1,6)=9.21$,$p<.01$ such that handed, right eye dominants non-artists had significantly faster reaction times ($M=810.09$,$SD=98.78$) handed non-artists, although the opposite trend for eye dominance was shown, this effect was

not significant. In artists, there was no significant interaction between handedness and eye dominance. No other effects were significant. (Ascher, 1999-2000, p. 152)

The tests may have been invalid because they were not difficult enough to obtain significance. Although the sample was selected on specific criteria, the sample size was too small to obtain accurate results to confirm the hypotheses that

1) Gender on performance on mental rotation tasks is not affected by artistic ability. However, past research has indicated that males perform better than females on mental rotation tasks, where subjects need to imagine how an object will appear in a different perspective (Kimura 1999; Masters 1998; Masters and Sanders, 1993; Peters, Laeng, Latham, Jackson, Zaiyouna, and Richardson, 1995; Resnick, 1993).
2) Artists have higher levels of mental rotation abilities than non-artists. In past research, strong relationships occurred between high spatial task performance, which consisted of mostly mental rotation tasks and certain artistic activities (drawing, mechanical drawing, jewelry making, and photography) and art courses (architecture, drafting, studio arts, and applied design) (Olsen, Eliot, and Hardy, 1998 cited in Ascher, 1999-2000, p. 149).
3) Artists and non-artists do not have a differential hemisphere advantage for mental rotation (Ascher, 1999-2000, p. 152). Past research indicates "lateralization of mental rotation skills have found an effect for right hemisphere dominance of such tasks (Corballis, 1997; Yavuzer, 1997; Heidler, 1996; Nalcaci, Cicek, Kalaycioglu, and Yavuzer, 1997). The research of Voyer and Bryden (1990), indicated a "significant left hemisphere advantage in males and a marginally right hemisphere advantage in females" (Voyer and Bryden, 1990 cited in Ascher, 1999-2000, p. 150).

Gaylen R. Carlson and Eric Streitberger, associated with the Science of Education Program at California State University in Fullerton, California, compared formal reasoning responses of seventh and eight grade students on three different tests on formal reasoning (Carlson, and Streitberger, 1983, p. 134). All tests contained the same information; only the mode of giving the test was different: a three-dimensional test, a two-dimensional test, and a self-administered, paper and pencil test. If there were little to no difference in test scores, then educators would have the ability to choose any method of giving tests. Especially if time and money was a factor, the paper and pencil test would suffice. The problem with this study is that teachers were allowed to administer two of the three modes of testing to their students. Each group of students only took one type of test. A threat to external validity, specifically, treatment diffusion, could have resulted to influence the test scores because the teacher gave one test to one group one week and another test to a different group the next week. Possibly the students talked to each other about the test.

The null hypotheses are:

(1) There is no difference in overall mean scores among three alternative tests (three dimensional, two-dimensional, and the paper and pencil tests).

(2) There is no difference in individual test item difficulty among the three tests.

(3) There is no difference in subjects' preference for the three tests when subjects are asked to compare a particular test with the other test they have taken.

(Carlson, and Streitberger, 1983, p. 134)

In this quasi-experimental research design the subjects were seventh and eight grade students enrolled in science classes in Orange County, California, who were divided by cluster and simple random sampling into three groups: students taking a 3-d demonstration test (n=129), a 2-d

demonstration test (n= 136), and a pencil and paper test (n=111). The classes were from a number of schools of similar economic and social areas. Atypical students were dismissed from the study. The students mean age was from 12.5-13.5 years old.

The measurements and instruments were three different test designs containing the same information, based on Lawson's (1978) design and format (Carlson, & Streitberger, 1983, pp. 134-145): one test was an actual three-dimensional demonstration test done in a laboratory with three-dimensional equipment, referred to as the 3-d demonstration test, which physically showed the sequence of events of an action; one test was a two-dimensional demonstration of the same test, referred to as the 2-d demonstration test, with life sized cardboard images of the demonstration and action sequences to the final image; and one test was a paper and pencil written test of the same demonstration with small diagrams and words to describe the actions of the demonstration. All multiple choice type responses for each task or test were identical for each test. The authors and an assistant scored the tests.

The procedure began with the selection of the subjects. Teachers, who attended a science institute for middle schools, utilized their students as subjects. Each teacher selected two classes (n = not given), which met at the same time. The classes were combined and random sampling was done to create the two groups (n = not given). Teachers were given specific instructions and protocol to follow in administering the formal reasoning tests. Teachers were allowed to choose two of three tests. The teacher gave one test to one group one week and another test to the other group the next week.

The results showed that the first hypothesis was rejected. The three-dimensional test scores were significantly better than the two-dimensional test scores. "The hypothesis that there is no difference among mean scores for the three tests was rejected at the 0.05 level" (Carlson, and

Streitberger, 1983, p. 137). The second hypothesis, there is no difference in individual test item difficulty among the three tests, was rejected. "A binomial *z*-test (Bruning and Kintz, 1968) was used to compare proportions of scores for each item on each test" (Carlson, and Streitberger, 1983, p. 138). The third hypothesis was confirmed; students did not prefer one test to another. "All subjects were required to select a number ranging from 1-10 on a continuum to describe how well they liked this test compared to other tests in general. A score of 10 represented the positive end" (Carlson, and Streitberger, p. 139).

There was a significant difference in the test scores between the three-dimensional test and the other two-dimensional tests. Average scores for the paper and pencil, the two-dimensional demonstration, and the three-dimensional demonstration tests were 6.09, 5.94, and 6.12 respectively. These three means were statistically the same" (Carlson, and Streitberger, 1983, p. 138). It was concluded that using three-dimensional materials was the reason for the higher test scores. However, the paper and pencil test is still cheaper, easier, and accurate enough to administer than the three-dimensional test.

John Eliot and Harold McWhinnie, College of Education, University of Maryland, College Park, Maryland, studied the spatial abilities of professional art students at a large major private art school. "The purpose of this study was to develop a data bank of test scores on the spatial abilities of a group of professional art students who would be expected to do very well on such tasks of non-verbal abilities and in matters of fluid cognitive functioning" (Eliot and McWhinnie, 1990, p. 4)

In this correlational study the hypothesis tested was that men would score higher on spatial ability tests than women. Convenience sampling formed the group of incoming freshman (n=112, n not broken up into men and women) at an arts school, who were tested with the

Revised Eliot Spatial Dimensionality Test Battery (Eliot, 1994) in the fall of 1987. The test contained 8 sub tests: Embedded figure test (ets), Card rotations tests, paper folding task, horizontal and vertical rotations, card perspectives, copying test, and a vocabulary test. In this study the test was addressing spatial skills, which "have been identified as components of general fluid cognitive abilities, perceptual field independence, and the ability to perceive three-dimensional spatial relationships. All of these elements would seem to be the key skills for success in art school" (Eliot and McWhinnie, 1990, p. 3).

Results showed that there were no significant differences in test scores between men and women. No statistics were provided in this study, only Tables 1-4 (Eliot and McWhinnie, 1990, pp. 11-14). "The construct validity of [their] spatial tests for this specific population was very high" (Eliot and McWhinnie, 1990, p. 3). In terms of spatial skills there was a high correlation between general fluid cognitive abilities, perceptual field independence, and the ability to perceive three-dimensional spatial relationships (Eliot and McWhinnie, 1990, p. 3).

Eliot and McWhinnie hope they can use these studies, which they had been doing for the past four years, to generalize about the interrelationships of these spatial skills to the general population. Elements of flexibility and strategy shifting are important in a visual arts education. By studying the professional fine art student may "give insights into the nature of the fluid dimension of general intelligence that no other special population could render to the researcher in cognitive science" (Eliot and McWhinnie, 1990, p. 10).

Michael Peters, Ph.D., Bruno Laeng, Kerry Latham, Marla Jackson, Raghad Zaiyouna, and Chris Richardson, Department of Psychology, University of Guelph, Guelph, Ontario, Canada, studied how sex differences affected the performance on three different versions of a mental rotations test based on Vandenberg's Mental Rotations Test (Vandenberg and Kuse,

1978) by using statistical procedures of a meta-analysis in a quantitative review. Their purpose was to focus on a large sample of subjects by examining the sex differences of their scores with respect to academic subjects, increased difficulty of a revised test, menstruation cycle in females, practice effects, handedness (writing with the left or right hand), and a comparison with other spatial ability tests. They hypothesized that sex differences would ensue in all of these areas.

Vandenberg's Mental Rotations Test (MRT) (Vandenberg and Kuse, 1978) was used in all of these studies for three reasons: "There are no difficulties in identifying this as a test of spatial abilities...This test favors male subjects in practically all published studies, across cultural boundaries, and the effect sizes are appreciable" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 40). The test provided a starting point from which to examine the meaning of sex differences in spatial performance.

There were three versions of the MRT, each with 24 items. The MRT(A) was close to Vandenberg's original test redrawn; Vandenberg's test had 20 items (Vandenberg and Kuse, 1978). Each item had one object and four choices of the object that were rotated around a vertical axis (The subject had to select the two correct choices.); MRT(B) was the MRT(A) in a different order; and MRT(C), a very difficult version of the MRT(A) test, requiring the object's choices to be rotated around the top/bottom and the left/right axis.

In the principal correlational study of meta-analysis, stratified sampling formed undergraduate students (n=636) at the University of Guelph from different academic programs: the sciences, composed of engineering, biological, and physical sciences (n= 177 men, n=135 women); and the arts composed of social sciences, arts, and humanities (n=102 men, n= 222 women). They participated in this study on a voluntary basis. The average age for men was 21.3 and for women was 20.5.

In the procedure for this study, before each test students were given a questionnaire asking about their left- or right-handedness (writing with their left or right hand) and how often they played with computer games such as "Tetris" or "Block –out". Women were asked if they took birth control pills, what was the last day of their last period, and if their menstrual cycle was regular. All questions were optional. All students were given the MRT(A). A subset of students was given a mental rotations test of the frontal plane, a card rotation test, and a Picture Folding Test (Ekstrom, French, Harman, and Dermen, 1976). "A within subjects design allowed evaluation of how sex differences for the three tests would compare for given subjects" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 43). Results reached a significance for sex differences: males outperformed females, "F (1/632)=135.75 p<.0001 *ES .177* Power 1.000" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 43) on all of these tests. This was true in both academic programs. "The effect size calculation shows that 17% of the variance in scores was accounted for by this variable" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 43). To control for the differences in the performance of the students in the different academic areas, z scores were used. "Results showed that only 15% of the females had z scores in excess of the mean z score of the males, and this falls short of the 25% predicted by Harris' model" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 43).

"The effect size of Academic Program was weaker; it accounted for 6.9% of the variance in scores" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 43). The performance of handedness was insignificant in comparison to sex (no statistics cited), but there was a significant interaction between academic programs and handedness. "The means suggests that lefthanders in the science programs performed better than righthanders and righthanders in

the arts program performed better than lefthanders" "$F(1/627)=51.50$ $p< .0001$ *ES* .08 *Power* 1.000" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 45). Each sex found the same degree of difficulty on each item, using the Pearson correlation coefficient =.93 (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 45). If art majors in the arts program were given the test separately from the social sciences and the humanities, the results may have been not so significant. Artists may have strong spatial skills.

A subset of subjects was given a questionnaire about their processes and strategies used while performing the MRT. On the questionnaire "more males than females used the nonverbal strategy ($X^2 = 5.5$, *df* 1, $p< .018$). 37.8% of the females vs. 15.6% of the males stated that they used movements of the fingers, hand, or pencil to help with the rotation performance ($X^2= 10.7$, *df* 1, $p< .001$)", and males who rotated parts of the figure did worse than males who rotated the whole figure "$F(1, 151) = 4.05$ $p < .05$, *ES* .03 *Power* .513" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 46). Males and females who verbalized their strategies did worse than those who did not. "The main effect of strategy was $F(1, 160 = 6.22$ $p< .01$ *ES* .04 Power >690"(Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, pp. 46-47).

Subjects (n=438) were given a questionnaire, asking them the frequency with which they played computer games. "A significant main effect of sex was found, (F(, 436)=34.4 p<.00001, ES .07, Power 1.000), which was of small magnitude" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 47). Although men played computer games more than women, there was no correlation between frequency of game playing and the MRT(A) performance. They were also asked if they liked the test. A subset of students, (n=136) responded; men liked it more than women "($F(1,132) =8.68$, $p < .004$, ER .06 , *Power* .831) and students in the science programs liked it more than the arts programs "($F(1, 132) = 14.5$, $p <$

.0001, ES .10; *Power* .965)" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 47). There was no relationship between liking the test and doing well on it (no statistics cited). These same subjects (n=136) commented on their playing with Lego blocks. There was no relationship between playing with Lego blocks and MRT(A) performance with men, but with women there was a relationship "(.21, $p < .05$)" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 48).

In another study, the MRT(A) and the MRT(B) were tested on different subjects (n=66, n=129, respectively). There were no significant differences on the two tests. One could be used in place of the other or used as a posttest (no statistics cited).

MRT(C) was given to subjects (n=94), who had taken the MRT(B). Sex difference is weaker in the MRT(C). "Separate ANOVAS for the main effect sex for the two versions indicate that the magnitude of the effect size for MRT(B) is twice that for MRT(C)" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 49). In Table 5 the MRT(B) on Sex is "F(1, 92) =27.8 $p < .00001$ *ES* .23 *Power* 1.000 " as compared to MRT(C) on Sex "F(1, 92) = 12.2 $p < .001$ *ES* .12 *Power* .931" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 49). "80% of the difference in performance in individuals is due to factors other than sex" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 54).

On the menstrual cycle phase, there was "no significant effect for the phase of cycle" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 49) but there was an effect of using contraceptive pills. However, the effect size for taking the pill was very small, "accounting for only 3% of the variance in MRT scores" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 49). One study believed women performed better on spatial tasks during menstruation (Hampson and Kimura, 1992), but they did not use the MRT. Another study used

the MRT and found a "Higher performance in females who are taking the contraceptive pill" (Silverman and Phillips, 1993 cited in Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 50). In general, the variable, menstrual cycle, will not confound the conclusions, but it may be affected by some individuals (Hampson and Kimura, 1992).

In another study the performance on the MRT(A) to practice was investigated. Twenty-seven subjects were given the MRT(A) once a week for four weeks. There was a main effect for Sex and Session: Sex effect was "$F(1/23 = 5.4\ p < .03\ ES\ .19\ Power\ .605$"; Session effect was "$F(3, 69) = 45.8\ p < .0001\ ES\ .67\ Power\ 1.000$" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 51).

In another study, MRT(A) was compared to the Paper Folding Test (PFT) and the Card Rotation Test. Of the data collected on 603 subjects, who took the PFT, there were significant effects on sex and academic program: program effect was "$(1,599) = 66.64\ p< .0001\ ES\ .10\ Power\ 1.000$"and the sex effect was "$(1,599) = 3.69\ p <.055\ ES\ .10\ Power\ .482$" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 52).

In the last study, Card Rotation Test, the PFT, and the MRT(A) were compared. Fifty-four men and 47 women were administered the tests in this order. The only significant sex difference was on the MRT(A). For the mental rotation test the results were "$F(1, 99) = 15.8\ p< .0001$, ES $.14\ Power\ .976$" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 53). Research findings confirm that the PFT and the Card Rotation Test should not be used as tests "that yield reliable sex differences for populations of university students" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 53).

Researchers concluded that there were sex differences on the mental rotations tests, which supports other research, where men out perform women (Jahoda, 1980; Oosthuizen, 1991;

Stumpf and Klieme, 1989). "'The percent of variance' accounted for provides a more informative measure of the effect size. Using Cohen's (1969) proposed classification of effect size (.25) = small, .25 to .50 = medium, > .50 = large), our observed effect sizes fell into the small-lower end of the medium range" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 53). The MRT was used for correlating spatial relations and sex differences. The reason for this follows a circuitous route. Is it that men perform better than women on the MRT, because they do better on spatial tasks or because men have better spatial tasks, they have higher scores on the MRT? It is difficult to know which influences the other: the ability to do spatial tasks or doing well on the MRT. More research is needed to give validity to this test.

Researchers concluded, "However, the link between spatial ability as assessed by MRT (and there is currently no better test) and performances in mathematics and science is by no means well established" (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 54). There may be "a direct link between mental rotation and motor mechanisms" (Pellizer and Georgopoulos, 1993). A limitation of the study is differential selection of participants. The students were not randomly selected, but taken from one university.

Roger N. Shepard and Jacqueline Meltzer (1971), in the Department of Psychology at Stanford University, studied the reaction time that subjects required choosing the correct angular difference between two three-dimensional objects, drawn in two-dimensional perspective drawings. There are tremendous flaws with this research. The study used convenience sampling of eight subjects, and gave no known demographics for them. It did not state if they were chosen by random selection, what were their ages, sex, or past background. The "angle through which different three-dimensional shapes must be rotated to achieve congruence" was not defined

(Shepard and Meltzer, 1971, p. 703). However, a large comprehensive test of 1600 items was administered, which gives a large amount of data to correlate.

In this correlational research the two hypotheses were: the reaction time of the subjects "increase[s] linearly with the angular difference in portrayed orientation and [is] longer for a rotation in depth than for a rotation merely in the picture plane" (Shepard and Meltzer, 1971, p. 701).

Eight subjects were selected, but the research did not state if random selection was used, what were the demographics of the subjects, the age or sex of the subjects, or their background. Shepard and Meltzer (1971), created this test, which consisted of 1600 pairs of perspective line drawings. The 1600 perspective drawings consisted of ten different objects, which were rotated in twenty-degree increments either by the picture plane or by depth around a vertical axis. Each object contained "ten solid cubes attached face-to-face to form a rigid arm like structure with exactly three right-angled elbows... 1600 pairs were grouped into blocks of no more than 200 and presented over eight to ten 1-hour sessions" (Shepard and Meltzer, 1971, p. 702). Half the pairs were congruent. The test, which was done on a computer, began with a warning bell initializing the view of the stimulus pair, then a timer began. A lever-pulling response signaled the subject's reaction time, terminated the visual image, and recorded the response time. Subjects were asked to respond as quickly as possible.

Results showed that in "all sixteen cases the functions were found to have a highly significant linear component ($p<.001$) when tested against deviations from linearity. No significant quadratic or higher-order effects were found ($p<.05$)" (Shepard and Meltzer, 1971, p. 703). In other words, an increase in the degree of rotation between the pair of objects caused an increase in the reaction time of the subject. Also, the overall mean reaction time of determining

two incongruent pairs, was nearly a second longer than recognizing the two congruent pairs (Shepard and Meltzer, 1971, p. 703). The hypotheses were confirmed. The larger the angular differences between the pair of objects, the longer were the reaction times. For large angular differences the reaction times were longer for pairs of objects rotated in the picture plane as compared to pairs objects rotated in depth. Shepard and Meltzer (1971), referred to this process of rotation as some sort of "mental rotation in three-dimensional space" (Shepard and Meltzer, 1971, p. 703).

This research was studying an aspect of spatial ability, mental rotations, in the hopes to define it. They called it "mental rotations" because, they hypothesized, it is the cognitive process required to perform the task. However, they acknowledged that further research is needed to clarify their findings. Defining and measuring mental rotations may help to understand, predict, and train this area of spatial ability, which may be necessary in fields that require spatial ability, such as mathematics, design, architecture, engineering, and physical sciences.

Dr. Steven G. Vandenberg and Allan R. Kuse at the Institute for Behavioral Genetics, University of Colorado (1978), created a paper and pencil test of three-dimensional spatial visualization to measure object-based transformation ability, the mental rotation of objects, based on the research by Shepard and Meltzer (1971).

In this correlational study the hypothesis was that this test will support the results of the test by Shepard and Meltzer (1971), and it was related to other tests of spatial ability. The method of selecting the sample was unclear, although its size was substantial. The test was given to different samples with high reliability.

The test was administered to university students, high school students, and elementary school students. However, the method of selection was not discussed. One test was conducted with a

sample of adults and adolescents of ages fourteen years or older (n=3,268). It was not broken down into male and female. Another test utilized a similar sample (n=336). For two other tests, which compared this test to other spatial abilities tests, samples were Americans of European ancestry between the ages of 14 and 60 years old, living in Hawaii (n=456 and n=3,435).

This test used two-dimensional drawings of three-dimensional objects, originally generated by a computer. The test contained twenty items in five sets of four items. Each item has a criterion figure, which were ten connecting cubes, and four corresponding figures that had been rotated around a vertical axis. Two correct choices were rotated around the vertical axis, and the two incorrect choices or distracters, were rotated, mirror-images of the criterion or other structures. The test was administered in three parts: a sample problem section and two problem sections. The sample problem section contained a written cover sheet, giving two examples of items and their correct choices, and three examples with the correct answers below them. The two problem sections were each five minutes, totaling ten minutes to complete this part of the test. The recommended way of scoring was to give two credits for a line with both choices correct, none if one choice was incorrect, but the other one was correct, or if both were incorrect. If only one choice was selected, one point was given. The highest score on the test was 40.

The results showed that the reliability is satisfactory, using the Kuder-Richardson reliability coefficient (N = 3268)=.88 (Wilson, Defries, McClearn, Vandenberg, Johnson and Rashad, 1975), with a sample of ages fourteen years old or older and the test-retest reliability coefficient (N =336) =.83 after an intervai of one year or more (Vandenberg and Kuse, 1978, p. 600). In an age corrected sample (n=456) the test-retest reliability after a year or more was .70 (Kuse, 1977 cited in Vandenberg and Kuse, 1978, p. 600). Other tests compared the scores of four spatial ability tests with the samples in Hawaii (n=456 and n=3,435). The scores of the tests suggest that they are

comparable. The tests administered were the Mental Rotations Test, Spatial Relations subset of the Differential Aptitude test (Bennett, Seashore, and Wesman, 1947), the Chair-window Test, and the Identical Blocks test (Stafford, 1962). The results of "split-half reliabilities on the corrected by Spearman-Brown formulas were .79, .77, .69, and .78" respectively (Vandenberg and Kuse, 1978, p. 601). Men performed better than women on all four of these tests. (Data for this was given in a table format and not in the body of the paper.) No data was given on the elementary school sample. However, studying the development of spatial ability at an early age may be helpful to understand how it affects sex differences at the onset of puberty.

INSTRUCTION TO INCREASE SPATIAL ABILITY

Justine Baker, Ph.D., at the Department of Counselor, Secondary, and Professional Education, West Chester University, West Chester, Pennsylvania (1990), performed two studies both dealing with spatial abilities and training: 1) investigate[d] the kinds of spatial strategies and personal experiences, both nonacademic and academic, that distinguish students preparing for high spatial careers from others; 2) focus[ed] on the effectiveness of spatial training incidentally given during a two month period in mathematics courses" (Baker, 1990, p. 1).The two were integrated to the extent that spatial abilities would be enhanced by academic experiences.

Various researchers have defined spatial ability. "Spatial ability may be defined as the ability to generate, retain, and manipulate abstract visual images" (Lohman, 1979, p. 188 cited in Baker, 1990, p. 2). He believed there are three categories of spatial abilities: spatial relations, which is linked with mental rotation of objects and to a lesser extent, speed of performance; spatial orientation, which relates to various imagined perspective in space by either the stimulus to the problem solver; and visualization, which is associated with paper folding and puzzle completion tasks (Lohman, 1979, p. 188 cited in Baker, 1990, p. 2). McGee (1978), defined two spatial

abilities: spatial visualization, which involves mental manipulation, rotation, twisting, and inverting of pictorially presented visual stimuli and spatial orientation, which encompasses the aptitude to remain unconfused by changing orientations of a presented configuration in relation to the positional orientation of the observer (Baker, 1990, p. 2). Ekstrom (1976), believed that visualization required mental manipulation of a figure by its restructuring into components; spatial orientation requires manipulation of the whole figure (Baker, 1990, p. 3).

In this causal-comparative study Baker (1990), had three hypotheses for the first study:

> 1) Students preparing for high spatial careers would perform better in spatial reasoning; 2) high spatializers would report more spatially enriching nonacademic and academic experiences; 3) high spatializers would employ more efficient spatial strategies, such as the use of mechanical drawing schemas to compare flat figure to the three-dimensional analogues and rapid holistic rotation to compare three-dimensional block-like objects. (Baker, 1990, p. 1)

Cluster sampling was composed of undergraduate students (n=126: mean age 21 years; SD= 5.0) in eight intact classes at a large university in the first study. The experimental group was two architecture classes, four engineering classes, and one computer science class, which were thought to be high spatializers. The control group was the speech communication class, which was thought to be low spatializers (Baker, 1990, p. 6). A correlational design was selected to measure the strength of association between career objective and spatial reasoning and between spatial reasoning and background experiences. A multiple regression was used to help explain how spatial reasoning may be affected by other variables such as major, age, experiential background, strategies and gender (Baker, 1990, p. 6). The instruments were (cited in Baker, 1990, p. 7): Vandenberg's Mental Rotations Test (known as MRT) to measure three-dimensional

orientation (Vandenberg and Kuse, 1978); ETS' Surface Development Test (known as SDT) to assess three-dimensional spatial visualization for three-dimensional spatial orientation (Thurstone, 1938; Ekstrom, French, & Harmon, 1976); Whole Numbers Mental Computation Test (WNMCT), a self constructed instrument with content validity, but not tested for construct validity; and a Spatial Reasoning Questionnaire, a not yet validated self-constructed instrument, to collect data on noncognitive variables "such as age, gender, class, major, and experiential background" (Baker, 1990, p. 7). All of the tests and questionnaire were administered during one class time, taking about 55 minutes.

The second study, a quasi-experimental design, focused on the increase in spatial visualization and spatial orientation, conducted over a two-month period. Cluster sampling at a medium-sized university was formed by two sections of an undergraduate class in a mathematics course for elementary education majors (n= 60: mean age 21.9) and by two sections of an undergraduate class in a mathematics course for liberal arts majors (n=59: mean age 21.0) (Baker, 1990, p. 8). The procedure consisted of a pretest (the MRT, SDT, and a questionnaire), instruction, and a post-test (the MRT, SDT, and a second questionnaire).

In the first study, spatial visualization aptitude increased significantly with school related experiences, but not for spatial orientation aptitude (statistics listed in a table format, not written out) (Baker, 1990, p. 15) that in stepwise multiple regressions, "The best single predictor of the MRT score was the SDT score (R Square = 0.31703, $F < 0.001$). Gender increased the predictive powers of spatial visualization ability by almost nine percent (R Square = 0.40498)." Men scored higher than women in mental rotation "unstandardized coefficient B = -5.991771)", which may be because they played with blocks more than women when growing up (Baker, 1990, p. 35). Nonacademic background accounted for about a seven percent increase (R Square = 0.47321)

(Baker, 1990, p. 13). "For spatial visualization, academic experiences are important; for spatial orientation nonacademic experiences are important" (Baker, 1990, p. 35). There were "correlations between spatial orientation and major and spatial visualization and major suggest that those preparing for high spatial careers perform better in these two important three-dimensional skills" (no written statistics, only Table 3) (Baker, 1990, p. 8). Students' answers on the questionnaire listed spatially enriching activities, both inside and outside the classroom, which may have helped them do well on the cognitive tests (Baker, 1990, p. 12).

In the second study results showed that there were significant gains for both groups in three-dimensional visualization and three-dimensional orientation performance (No cited statistics). There were "significant correlated t test values for both spatial variables for the education group (t, 44=8.07, $p<0.001$ for SDT; t, 44=-2.38, $p<0.05$ for MRT) and for the liberal arts group (t, 37=-.542, $p< 0.001$ for SDT; t, 37+-2.80, $p<0.01$) (Baker, 1990, p. 15). However, limitations resulted from practice effects and experimental mortality.

Baker (1990), concluded, "High spatial abilities are thought by some researchers to be prerequisite for entrance into a wide range of scientific careers." (Baker, 1990, p. 1). High spatializers will have more career opportunities open to them (McGee, 1979; Smith, 1964 cited in Baker, 1990, p. 1). Baker (1990), believes that spatial programs should begin in an elementary school academic curriculum, especially focusing on girls, because they consistently scored lower than the men in this study and it may give them the opportunity in increase their spatial ability and go on to choose high spatial careers. Even at the college level, increasing spatial skills may help undecided students choose a career choice (Baker, 1990, p. 36). More true experimental research is needed.

Katheryn Holliday-Darr is presently conducting this research at Penn State-Erie in conjunction with a project team comprised of an instructor in engineering graphics, an associate professor in experimental psychology, a senior instructional designer, a graphic designer, and a programmer/analyst. Dawn Blasko is at Penn State-Erie. Carol Dwyer is at Penn State-University Park (Holliday-Darr, and Dwyer, 2000, p. 5). They are providing methodology to test for and increase spatial ability in college engineering students, and hopefully use these tests in other discipline areas. The hypothesis to be tested is: students can increase their spatial skills through computer-generated programs that teach spatial skills. The goals of the project "are to develop a program that is highly accessible, assesses current skills, provides immediate feedback, and provides training exercises tailored to each student's skill level" (Holliday-Darr, Blasko, and Dwyer, 2000, p. 5)

This quasi-experimental research design tests theory and is in the process of being developed. It will first be used in a freshman seminar class for engineering students, but the authors hope "the program will be made available to high schools and outreach programs to help students interested in fields which require visualization skills" (Holliday-Darr, Blasko, and Dwyer, 2000, p. 4). Students are allowed to take the course as a one-credit independent study as an incentive to take the course.

The web-based computer program, which is being developed and is on the web at http://viz.bd.psu.edu.edu/viz/, contains three different exercises, based on three different types of spatial skills identified in a large meta-analysis (Voyer, Voyer, and Bryden, 1995). They are:

> (1) Spatial perception (the ability to determine spatial relationships among objects despite distracting information), (2) spatial visualization (the ability to manipulate complex spatial information when several stages are needed to produce the correct solution), and (3) mental

rotation (the ability to quickly rotate in their imagination 2 or 3 dimensional objects). (Holliday-Darr, Blasko, & Dwyer, 2000, p. 6)

They will first access the participant's three types of spatial skills, and then based on his/her scores, it will provide exercises to improve that skill. Spatial perception will be measured using the Piaget Water Test (Piaget & Inhelder, 1956), i.e. a water bottle with a liquid line and an empty, tilted water bottle in which to draw the water line. Spatial visualization will be measured using an adaptation of the paper folding test Differential Aptitude Test: Space Relations (DAT:SR) forms S & T (Bennett, Seashore, and Wesman, 1973), i.e. look at an unfolded object of connected squares and choose the correct folded cube formation. Mental rotation will be measured using the Mental Rotation Test (http://www.olemiss.edu/). It only tests for mental rotation abilities, i.e. rotate connected cubes in space (Vandenberg and Bryden, 1995). When a student gets a wrong answer, the computer will give the correct answer and give a program at the level of the student to increase his/her ability in this area. The computer will store all of this information. Many different types of software programs are being investigated to be used to collect this information such as Authorware, Solidworks, Pro-Engineer, Photoshop, and Flash (Holliday-Darr, Blasko, and Dwyer, 2000, p. 8).

This web-based program may be especially important for women, who may not be in many technical fields such as engineering and tend to do poorly on some spatial tasks, i.e. mental rotation. Social stereotypes reinforce that women are less competent in mathematics. If "spatial skills are viewed as a purely innate ability then any person who has been told that they have poor spatial skills will be likely to avoid activities and courses that might actually improve those skills" (Holliday-Darr, Blasko, and Dwyer, 2000, p. 5). This happens in cultures such as the United States. If "a training program that demonstrates to a student that spatial skills CAN be

improved [it] should have an attitudinal impact that goes beyond basic skill improvement" (Holliday-Darr, Blasko, and Dwyer, 2000, p. 5).

> The ability to visualize objects and situations in one's mind and to manipulate those images is a cognitive skill vital to many career fields, especially those that require work with graphical representations such as visual arts and engineering. Spatial abilities have been widely studied and are known to be fundamental to higher-level thinking, reasoning, and creative processes. However, individuals vary widely in these skills. Research on mental imagery has shown that several of the component skills can be improved by training. (Holliday-Darr, Blasko, and Dwyer, 2000, p. 4)

Visualization skills and manipulating objects may be necessary in the fields of engineering, visual arts, and other fields that require spatial ability. Hopefully, an increase in the retention of spatial ability in engineering students, especially women will build their visualization skills, and perhaps their confidence level. This research is the first phase of the program. The second phase will include more exercises designed to enhance the visualization skills in other disciplines. Holliday-Darr, Blasko, and Dwyer (2000), believe that spatial skills can be increased through regular practice and training. They believe interested schools/institutions should work together to make this happen.

A threat to external validity with this research is selection-treatment interaction because there was no random sampling of the group. A cluster group from one college is being tested. A different college population may provide different results in the study. A threat to internal validity is mortality because some students may drop out of the course, causing fewer students to be studied. However, a pretest, instruction, posttest format is a highly effective means of testing for increased learning.

Seddon and Shubber, at the Chemical Education Sector, School of Chemical Sciences, University of East Anglia, Norwich, England, studied if students learning formal relations, such as spatial relationships and visualize rotations, from instructional programs changes over the age range of 13-17 years, in order to test Piaget's theory, which is when concrete formal operations occurs (Piaget and Inhelder, 1971 cited in Seddon and Shubber, 1985, p. 99). Seddon and Shubber suggested the following:

> At a relatively advanced level, students must be able to visualize how the diagrams should change to represent the effects of rotating a structure, or what amounts to the same thing, visualize what the diagram would look like, if the structure is viewed from a different direction. At a lower level, students must merely understand the spatial relationships portrayed in these diagrams. In particular, they must realize that the diagrams represent a structure with has depth, as well as width and height. (Seddon and Shubber, 1985, p. 97)

The hypothesis stated that students who have problems visualizing rotation in molecular diagrams improve their ability with remedial instruction. The independent variables were the tests given to measure for visualization and rotation. The dependent variable was the results of these test scores.

All of the tests in this study were Arabic translations and were administered in previous studies (Seddon, 1984b; Evans and Seddon, 1978; and Nicholson and Seddon, 1977b;), but there was no evidence of construct validity that they accurately tested what they said they were testing.

This true experimental research design was comprised of 300 subjects, all male students from three single-sex secondary schools in Bahrain. One hundred students at each school were divided into three age groups: 13-14, 15-16, and 17-18 years old. Each age group had an experimental group and a control group. There was no difference in ability between the different age groups.

The study was performed in Bahrain, a developing country, because it has been hypothesized that students with a general high ability have difficulties in understanding spatial relationships with out having to visualize (Peterson 1982; Walker, 1979; Miller, 1973; cited in Seddon and Shubber, 1985, p. 97).

The measurement was based on six different tests of formal operations: Cues Tests- contained four tests, which were an overlap test, a relative size test, a foreshortening of lines test, and a distortion of angles test; Framework Test- "to compare the relative magnitude of two displacements" (Seddon and Shubber, 1985, p. 101); Rotations Tests- look at a diagram and choose the correct image of the diagram rotated (Seddon and Shubber, 1985, pp. 99-102). The procedure was devised into three stages. Each school focused on only one of the above-mentioned formal operation, cues, frameworks, or rotations. In the first stage, the general ability of the students was assessed by administering a pretest to each group of students. The students were then randomly selected and placed into an experimental group and a control group. In the second stage, the experimental group was given instruction in the area in which they were given a pretest. In the third stage, the experimental and the control groups took a posttest of their respective area of learning.

With the significance level set at .01, the results showed that respect to age on the pretest, "the mean scores for the 13-year olds were significantly less than those of the other two age-groups combined, but that there was no significant difference between the means of the 15-year olds and the 17-year olds ($p>.05$)" (Seddon and Shubber, 1985, p. 104). Although most students failed on each pretest, the "results of analysis of variance reveal there is a significant increase in performance with chronological age" (Seddon and Shubber, 1985, p. 105). "Students learn significantly from the Frameworks and Rotations program" (Seddon and Shubber, 1985, p. 107).

It is unclear as to why only the Foreshortening program failed to teach (Seddon and Shubber, 1985, p.106). Test scores were higher from the pretest to posttest on the Rotations test, possibly due to the developmental age of the students, as Piaget suggested (Piaget and Inhelder, 1971). No statistics were presented in the study, only charts with a list of means and standard deviations.

The important message in this study is that spatial ability may be taught to these students. In all cases, "except the Foreshortening Cues Test, the means of the experimental groups were always higher than those of the controls (Seddon and Shubber, 1985, p. 105), as shown in the provided the graph and chart (Seddon and Shubber, 1985, p. 106). The 17-year olds learned significantly more than the other age groups, as shown in the provided the graph and chart (Seddon and Shubber, 1985, p. 106). Where E, the experimental group, and C, the control group, and the numbers are the ages of the subjects, "The means of groups E(15) and C(13) combined, and groups C(13)combined, and of groups C(15) and E(13) combined were not significantly different ($p>.05$)" (Seddon and Shubber, 1985, p. 106). No statistics were included for either of these findings.

CONCLUSIONS

Spatial ability is a cognitive function that is broken up into many components. However, researchers disagree on its definition. Piaget (1956), described spatial ability as a combination of three different skills: topological relationships (proximity, separation, order, enclosure, and continuity), projective space, understanding perspective, and Euclidean space, geometric shapes remain unchanged despite a change in position (Piaget, 1956 cited in Stix, 1992, p. 14). Arnheim (1969), was the first to coin the phrase visual thinking. He believed spatial ability was a combination of two parts, perception (visual thinking) and reasoning (cognitive thinking)

(Arnheim, 1986 cited in Sorby, 1999, p. 22). According to Lohman, "Spatial ability may be defined as the ability to generate, retain, and manipulate abstract visual images" (Lohman, 1979, p.188 cited in Baker, 1990, p. 2). He believed there are three categories of spatial abilities: spatial relations, which is linked with mental rotation of objects and to a lesser extent, speed of performance; spatial orientation, which relates to various imagined perspective in space by either the stimulus to the problem solver; and visualization, which is associated with paper folding and puzzle completion tasks (Lohman, 1979, p. 188 cited in Baker, 1990, p. 2). According to Haanstra (1996):

> Visual-spatial ability is a psychological concept derived from the psychometric approach to human performance. It can be described as a skillful set of responses to spatial tasks, such a reading a map or blue print, estimating the length of a string needed to tie a parcel, or imagining how a room will look after re-arranging the furniture. (Haanstra, 1996, p. 198)

Stix (1992), defined the global construct of visual-spatial ability into five groups: Visualization, the ability to recognize information without the manipulation of objects or operative thought (Dixon, 1983 cited in Stix, p. 107); Spatial ability, the ability to determine the relationship and patterns among objects; Visual-spatial ability (sometimes referred to as spatial ability), the combination of two functions: Spatial Orientation; and Spatial Visualization. McGee (1979), believed evidence suggests at least two spatial factors: spatial orientation is "an ability to perceive spatial patterns or to maintain orientation with respect to objects in space; [It] requires that a figure be perceived as a whole" (Ekstrom, French, and Harman, 1976 cited in McGee, 1979, p. 891) and spatial visualization "is the ability to mentally rotate, manipulate, and twist two- and three-dimensional stimulus objects" (McGee, 1979, p. 909).

Much research has been done on the area of spatial ability. This research addressed spatial visualization based on McGee's (1979) definition. Shepard and Meltzer (1971), studied this aspect of spatial ability, mental rotations, in the hopes of defining it. They called it "mental rotations" because they hypothesized that was the cognitive process required to perform the task. They developed a test for mental rotation, and found that mental rotation, a subset of spatial ability, may be tested and correlated to other tests of spatial abilities. Vandenberg (Vandenberg and Kuse, 1978), used Shepard and Meltzer's (1971), findings and created his own test, the Mental Rotations Test, which Vandenberg and Kuse (1978), used in their studies (Vandenberg and Kuse, 1978).

The reliability of the Vandenberg's Mental Rotation Test is satisfactory. The reliability is the Kuder-Richardson reliability coefficient (N = 3268)=.88 (Wilson, Defries, McClearn, Vandenberg, Johnson and Rashad, 1975) with a sample of ages fourteen years old or older. The test-retest reliability coefficient (N =336) =.83 after an interval of one year or more (Vandenberg and Kuse, 1978). "There are no difficulties in identifying this as a test of spatial abilities" (Peters et al., 1995, p. 40).

There may be concurrent validity in the test because it was correlated to other tests of spatial abilities, where the construct validity of the spatial tests was high (Eliot and McWhinnie, 1990; Vandenberg and Kuse, 1978; Baker, 1990). In terms of spatial skills, there was a high correlation between general fluid cognitive abilities, perceptual field independence, and the ability to perceive three-dimensional spatial relationships (Eliot and McWhinnie, 1990, p. 3).

In terms of education, visual images may be a necessary part of learning. Madeja (1997), believed that "Perception is a major player in the game of creating art. It is important to teaching all students, but particularly art students, how and what to see and how to analyze and make judgments as to what

they see" (Madeja,, p. 14, 1997). You can visually perceive an object, but to fully understand its form and its relationship in space, spatial skills are a necessity (Madeja, 1997). According to Stix (1992), "Spatial thinking occurs when visualization and rational thought are applied together"(Dixon, 1983, p. 56 cited in Stix, 1992, p. 12). Taking this a step further, in Gardner's (1993), Theory of Multiple Intelligences, one of the eight intelligences, Spatial Intelligence is "the ability to form a mental model of a spatial world and to be able to maneuver and operate using that model" (Gardner, 1993, p. 9). Spatial Intelligence is an important part of visual literacy. Visual literacy can be explained in terms of being able to use visuals for communication, thinking, learning, constructing meaning, creative expression, and aesthetic enjoyment (Braden, 1993). The visual literacy movement has always been tied to the field of education, where images have been utilized for instructional purposes. Without visual literacy, spatial ability might be extremely difficult, if not impossible to learn because instruction in spatial ability requires visual images (Braden, 1993). Unfortunately, "our educational system is to blame for the lack of emphasis on visualization and visual thinking skills" (Sommer, 1978 cited in Sorby, 1999, p. 23).

Although students might learn better with three-dimensional materials than two-dimensional materials, pictorial images with words are still better to stimulate learning than just words rather than each of them independently (Appelbaum 1993; Dwyer, 1988; Fleming, 1987; Carlson and Streitberger, 1983; Braden 1983; Duchastel, 1978; cited in Braden, 1993, p. 7). Stix (1992), supported this research, where preservice teachers lowered their anxiety level when they taught math with pictorial note-taking and not just with words. Therefore, it may be helpful to include three-dimensional materials or visual images in academic instruction. The more visual imagery a student receives, the stronger his/her spatial skills may become.

In fields requiring high spatial skills, engineering students need to be trained in spatial ability at an earlier age (Holliday-Darr, Blasko, and Dwyer, 2000; Lubojacky, Duzi, and Tercova, 1999). Other researchers also agree that spatial ability may be enhanced by instruction (Holliday-Darr, Blasko, and Dwyer, 2000; Baker, 1990; Seddon and Shubber, 1985).

Spatial ability is an essential skill utilized in all of these fields, including fields associated with art (Ascher, 1999-2000; Eliot and McWhinnie, 1990). Artists have higher levels of mental rotation abilities than non-artists (Olsen, Eliot, and Hardy, 1998 cited in Ascher, 1999-2000). It may lead to higher levels of critical thinking, which is an important skill all people should learn.

Some even studied the affect of gender on spatial ability (Kimura 1999; Masters 1998; Peters, Laeng, Latham, Jackson, Zaiyouna, and Richardson, 1995; Masters and Sanders, 1993; Resnick, 1993; Vandenberg and Kuse, 1978; Baker, 1990; Holliday-Darr, Blasko, and Dwyer, 2000; Ascher, 1999-2000; Voyer, Voyer, and Bryden, 1995; Ozer, 1987). Men scored higher than women in mental rotation. It may be because they played with blocks more than women when growing up (Baker, 1990). In another study, there was no relationship between playing with legos and performance on a mental rotation test, MRT(A), with men, but with women there was a relationship (Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995, p. 48). Gender did not affect the scores on spatial ability tests given to professional art students at an art college (Eliot and McWhinnie, 1990).

Research has shown that spatial ability may be important in all fields of study, including the sciences and the arts. Yet, much of the research investigated in this study used college age or older subjects. This population may perform differently on this test because they have had more life experiences to influence each study's results. However, no research has focused on high school students' performance on this test in comparison to: art ability, gender, academic

performance, outside activities, test-taking strategies and cognitive thought processes for taking the test, and the ease of taking the test.

This study hoped to gain insight into this age level's ability on this test in order to see if these factors would support or not support the research results of past studies. After assessing the results of this study, more research needs to be done to examine younger populations on these factors with a variety of age appropriate spatial tests and to develop a curriculum on spatial ability at all grade levels to strengthen spatial skills.

RELATIONSHIP OF RESEARCH STUDIES TO RESEARCH STUDY

Research points to the need to study all areas of spatial ability, including mental rotations, to understand its implications and importance in our lives. Shepard and Meltzer (1971), believed in defining and measuring mental rotations because it may help to understand, predict, and train this area of spatial ability, which may be necessary in fields that require spatial ability, such as mathematics, design, architecture, engineering, and physical sciences. Eliot and Smith (1983), supported these findings, associating a strong correlation between spatial ability and success in academic areas such as mathematics, interior design, physics, technical drawings, woodwork, and engineering because they require "analytical visual skills" (Baker, 1990; Eliot and Smith, 1983 cited in Orde, 1997, p. 273). McGee (1979), also agreed that spatial tests might predict spatial ability, which are used "for selecting workers for industrial jobs and predicting job performance and …for the prediction of success in vocational-technical training programs" (McGee, 1979, p. 894). According to Ascher (1999-2000), artists have higher levels of mental rotation abilities than non-artists. In past research, strong relationships occurred between high spatial task performance, which consisted of mostly mental rotation tasks and certain artistic activities (drawing, mechanical

drawing, jewelry making, and photography) and art courses (architecture, drafting, studio arts, and applied design) (Olsen, Eliot, and Hardy, 1998 cited in Ascher, 1999-2000, p. 149).

This exploratory research gathered information to study the mental rotation ability, a subset of spatial ability, of high school students, of which there is little available. It used Vandenberg's Mental Rotation Test (MRT) for mental rotations (Vandenberg and Kuse, 1978). Possibly giving a combination of spatial tests to high school students that have been developed to assess spatial ability such as (Sorby, 1999, pp. 24-26): Vandenberg's Mental Rotation Test (MRT) for mental rotations; the Minnesota Paper Form Board (MPFB) (Likert, 1970); the Differential Aptitude Test: the Space Relations (DAT:SR) for paper folding (Bennett et al., 1973); the Purdue Spatial Visualization Test (PSVT-R) (Guay, 1977) for mental rotations; and the 3-Dimensioanl Cube (3DC) for mental rotations (Gittler, 1998) may help to give a more complete understanding of the level of spatial ability of this age group. These tests may need further revisions to better assess spatial ability.

Spatial ability may be able to be predicted and then enhanced through instruction. If "a training program that demonstrates to a student that spatial skills CAN be improved [it] should have an attitudinal impact that goes beyond basic skill improvement" (Holliday-Darr, Blasko, and Dwyer, 2000, p. 5). Students with low spatial abilities may be able to go into careers they never thought was possible, because they may be able to improve areas of it that are weak and enhance areas of it that are strong. Those students who were unaware of their strong spatial skills may now have more career choices might be open to them. Sorby's (1999) research agreed with the need for instruction in these areas. Yet, "More research is needed on the training of spatial ability and its transferability to academic subjects" (Orde, 1997, p. 276).

Developing spatial ability in students might become a goal in education and art education because "it is possible that we will find spatial ability to be similar in importance to such traits as verbal or social intelligence" (Smith, 1965, p. 100, cited in Orde, 1977, p. 276). "It is suggested that art education, because of its perceptual emphasis, may improve general visual-spatial ability"; a goal of art education is perceptual learning or helping students see. (Haanstra, 1996, p. 198). Art might help with developing higher level thinking skills (Feldhous, 1992 in Orde, 1997, p. 276).

Baker (1990), believed that spatial programs should begin in an elementary school academic curriculum, especially focusing on girls, because they consistently scored lower than the boys in the study. It may give them the opportunity to increase their spatial ability and go on to choose high spatial careers. Even at the college level, increasing spatial skills may help undecided students choose a high spatial career (Baker, 1990, p. 36).

Few studies predict and instruct students at the elementary level through high school level to enhance their spatial abilities for career choices; most studies have been and are still being conducted at the college level, particularly for engineering students. If age appropriate tests could be developed to show the construct validity and predictive validity of spatial ability at all grade levels, students might have many more career choices open to them, especially women, and cognitive thinking might be enhanced by these spatial skills.

Gardner believed that people learn in different ways, or may be stronger in one intelligence than another. For example, this may enable an individual to excel in Spatial Intelligence, and be weak in Linguistic Intelligence or the other intelligences (Gardner, 1995). If art teachers could know students' spatial abilities through testing, they may have a reference point from which to start to instruct them to enhance and/or strengthen these skills, which may help students create

better artwork. Those students who are talented in art, but who are not doing well in other academic subjects may feel like a failure, when in reality they are gifted artists. Wouldn't it be wonderful to know right away through spatial ability testing if students, who think they are low achievers with low self-esteem, have strong spatial ability skills and may be able to improve them to help turn their life around and feel they have something to offer the world and succeed in life?

Perhaps the first thing to do would be to devise a longitudinal study for spatial ability knowledge where groups of elementary to high school students are tested for their level of spatial ability, placed in either an experimental or a control group that is or is not given instruction in spatial ability over the course of a few years, then retested for it. It may provide insight into how spatial ability training impacts students' lives. Would students with the training choose more spatially enriched elective courses at the high school level or consider a spatially enriched career?

Then, if the educational system developed a curriculum on spatial ability that may increase spatial skills, "which are known to be fundamental to higher level thinking skills, reasoning and creative processes" (Holliday-Darr, Blasko, and Dwyer, 2000, p. 4), the business world may reap the benefits of more well-rounded, creative, productive workers in the work force.

This study was concerned with high school students' performance on Vandenberg's Mental Rotation Test. Past research of mostly college age or older subjects has indicated that art ability, gender, and outside activities have influenced the test scores. This study examined if these results hold true for high school students.

HYPOTHESES

Hypothesis 1: Art and Non-Art Classes

Art classes score higher on the MRT than non-art classes.

Hypothesis 2: Comparison of Class Types

The following hypotheses compare MRT performance and class type:

a. Sculpture classes have significantly higher scores on the MRT than Drawing and Painting classes.

d. Drawing and Painting classes have significantly higher scores on the MRT than Studio Art Foundation classes.

e. Studio Art Foundation classes have significantly higher scores on the MRT than the Social Studies class and Psychology classes.

Hypothesis 3: Gender

Males score significantly higher on the MRT than females.

Hypothesis 4: *Visual-Spatial Activities*

a. Students who score high on the MRT also score high on the items in "In the Past" part of *Section 2* of the questionnaire. There is a positive correlation between the MRT scores and activities students did in the past.

b. Males who score high on the MRT also score high on the items in "In the Past" part of *Section 2* of the questionnaire. There is a positive correlation between the MRT scores and activities males did in the past.

c. Students who score high on the MRT also score high on the items in the "Now" part of *Section 2* of the questionnaire. There is a positive correlation between the MRT scores and activities students are doing now.

Hypothesis 5: Strong Academic Performance per Discipline

Students whose state their best academic subject (written either numerically or with a letter grade) in school this year, is in art, math, or science score higher on the MRT than those students whose best grade is in English or Social Studies.

Hypothesis 6: Ease of Taking the Test

There is a positive correlation between a student's MRT score and the ease of taking the test.

Hypothesis 7: Strategies Used to Solve Problems

Mental Rotation Strategy:

a. Students who mentally rotate the whole figure score significantly higher on the MRT than students who rotate a section of the figure.

b. More males than females mentally rotate the whole figure to solve the problems on the MRT.

Visual and Verbal Strategy:

c. Students who use a nonverbal, visual approach (abstract, mental images), score higher on the MRT than students who think through the steps verbally in their mind.

d. More males than females use a nonverbal strategy to solve the problems on the MRT. Females use a verbal strategy more than males.

Use of Body Movements Strategy:

e. Students who do not use movements of their fingers, hand, and/or pencil to help solve the problems on the MRT score higher than students who use movements of their fingers, hand, and/or pencil to help solve the problems on the MRT.

f. More females than males use movements of their fingers, hand, and/or pencil to help solve the problems on the MRT.

Independent Variables: Different levels of spatial ability in the following groups: art and non-art students, gender, academic performance, outside activities, strategies of taking the test, and the ease of taking the test.

Dependent Variable: Level of spatial ability, the scores on Vandenberg's Mental Rotation Test.

III. METHOD

PURPOSE

The purpose of this section is to describe the method used to test the hypotheses.

RESEARCH DESIGN

The research method was divided into two parts. First, a retrospective causal-comparative study compared the mental rotation ability, a subset of spatial ability, to five different types of classes of high school students, comprised of art and non-art students, to see which class type had the highest test scores on a mental rotations test (Vandenberg & Kuse, 1978). The effect was the score of the spatial ability test; the cause investigated was the spatial ability to perform mental rotations. The second part of the study used a quantitative, descriptive survey questionnaire. It supplied information to compare the mental rotations test to gender, academic performance, visual-spatial activities, test-taking strategies used while performing the test, and the ease of taking the test.

SETTING

The study was conducted at a suburban, public high school of about 1200 students in Westchester County, New York, near a major city. The ethnic configuration of the school was 83.1% White (not Hispanic), 13% American Indian, Alaskan, Asian, or Pacific Islander, 1.8% Black (not Hispanic), and 2.1% Hispanic. The school was nationally recognized for its educational excellence. Most of the 17,000 residents in this middle class to wealthy community were professional and business executives who demonstrated strong support for the educational system.

PERSONNEL

The personnel involved were the art teachers, the social studies teacher, and the psychology

teacher, who allowed the study to be performed. All were New York State certified, full-time, tenured teachers. Because the researcher knew the teachers, they were willing to allow their classes to participate in the study. They had no prior knowledge of the procedures, the test, or the questionnaire; they had not forewarned their students about the study. The principal at the school verbally granted permission to conduct this study. The researcher was a master's level student in art education at the College of New Rochelle, who lived in the area of the study.

SAMPLING METHOD

The target population was all high school students in art, social studies, and psychology classes in the United States. Sampling bias occurred because of nonrandom sampling of this population; there was a limited amount of time and resources for this study. As a result, the target population was assumed to be different from the accessible population. Purposive sampling was used to select art and non-art classes for this study.

Twelve intact classes participated in this study and not the random assignment of students (N=186). The break down of the classes is shown in Table 1. There were three different types of the art classes. The two Studio Art Foundation classes (n=33) in grades 9-11 were beginning level art classes with no previous art instruction at the high school level. The two Drawing and Painting classes (Advanced Drawing and Painting and Drawing and Painting 1) (n=26) in grades 9-12 had a prerequisite of a Studio Art Foundation class. The four Sculpture classes in grades 9-12 were comprised of three classes in Sculpture 1 and one class in Advanced Sculpture (n=42). The prerequisite for Sculpture 1 was Studio Art Foundation. The prerequisite for Advanced Sculpture was Sculpture 1. The non-art classes were a 10th grade Social Studies class (n=22) and three Psychology classes (n=63). The number of students in each grade was 44 ninth graders,

46 tenth graders, 58 eleventh graders, and 38 twelfth graders, which was 24%, 25%, 31%, and 20% respectively out of the total population.

Table 1: Class type, grades, and sample sizes

Classes	**Grade**	**# of Students**
2 Studio Art Foundation classes (one half-year and one full year)	Grades 9-11	n=33
2 Drawing and Painting classes (D & P): Advanced D & P and D & P 1	Grades 11-12	n=26
4 Sculpture classes: Sculpture 1 (three classes) and Advanced Sculpture (one class)	Grades 10-12	n=42
1 Social Studies class	Grade 10	n=22
3 Psychology classes	Grades 11 & 12	n=63
Total Number of Students		N=186

These classes were selected to provide a comparison of art classes (especially sculpture classes) and non-art classes. Sculpture classes were exposed to more three-dimensional projects than advanced drawing and painting classes, whose concentration was on two-dimensional projects. Studio Art Foundation classes were taking art for the first time in the high school and received instruction in both two-dimensional and three-dimensional assignments. The Studio Art Foundation classes were state mandated to take a year of art or music or a combination of the two; they elected to take art. The Social Studies and Psychology classes were used as a control group that had no exposure to art. If they were taking art, it was indicated in Section 2, the

visual-spatial activity section of the questionnaire. The selected classes were similar because they were all from the same high school and in the same grades.

MEASURING/DATA COLLECTION INSTRUMENTS

The two types of research designs needed in this study required their own method for gathering the data. One, the retrospective causal-comparative research used the measurement instrument, "Vandenberg's Mental Rotations Test" known as the MRT (Vandenberg and Kuse, 1978), presented in Figure 1. Two, the survey as shown in Figure 2, was a self-report questionnaire with structured items, "Questionnaire of Mental Rotations Experiences", designed for this study. It supplied information to compare the mental rotations test to gender, academic performance, visual-spatial activities performed in the past and the present (doing now), strategies used while performing the test, and ease of taking the test. The test was given before the questionnaire because *Section 4* of the questionnaire asked students to rate their ease of taking the test.

MENTAL ROTATIONS TEST

The Mental Rotations Test (MRT) by Vandenberg (Vandenberg and Kuse, 1978), published by Behavioral Measurement Database Services, was a paper and pencil test of three-dimensional spatial visualization, which measured object-based transformation ability, the ability to mentally rotate a figure, as shown in Figure 1. Its cost was $20.00. It was based on research done by Shepard and Meltzer (1971). It was originally constructed from India ink drawings. In 1996, Douglas, at the University of Texas digitized and reprinted the images. This public document did not require copyright permission, but instruments were for a single study only.

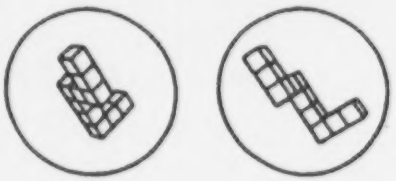
The test was divided into three parts: a sample problem part and two problem parts (Part I and Part II). The sample problem part contained a written cover sheet, giving two examples of

Date_____
School_____
Class_____
Grade_____
Sex_____

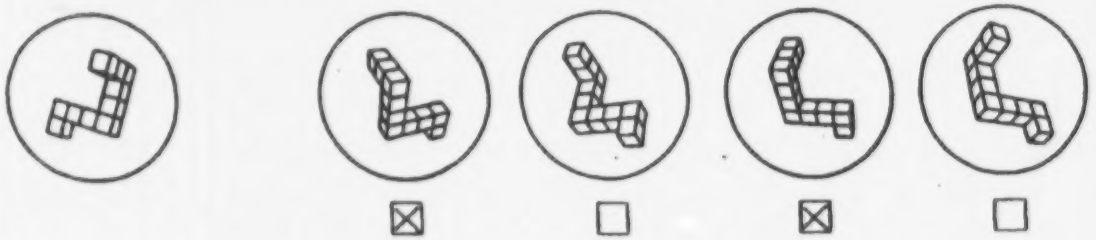
M.R.T. Test

This is a test of your ability to look at a drawing of a given object and find the same object within a set of dissimilar objects. The only difference between the original object and the chosen object will be that they are presented at different angles. An illustration of this principle is given below, where the same single object is given in five different positions. Look at each of them to satisfy yourself that they are only presented at different angles from one another.

Below are two drawings of new objects. They cannot be made to match the above five drawings. Please note that you may not turn over the objects. Satisfy yourself that they are different from the above.



Now let's do some sample problems. For each problem there is a primary object on the far left. You are to determine which two of four objects to the right are the same object given on the far left. In each problem always <u>two</u> of the four drawings are the same object as the one on the left. You are to put Xs in the boxes below the correct ones, and leave the incorrect ones blank. The first sample problem is done for you.



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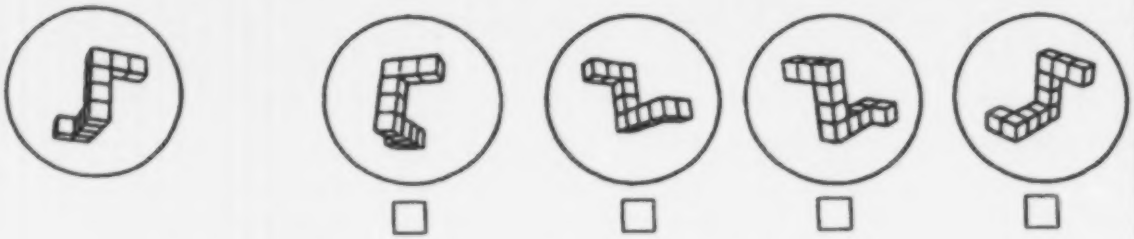
Adapted by S. G. Vandenberg, University of Colorado, July 15, 1971
Revised instructions by H. Crawford, U. of Wyoming, September, 1979
Images digitized and reprinted by Susanna Douglas, University of Texas, March, 1996

This is a public domain document and does not require copyright permission.

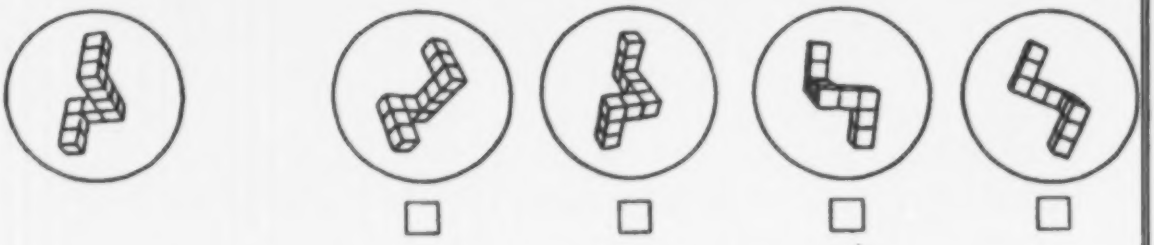
Figure 1: Mental Rotation Test by G.S. Vandenberg

Do the rest of the sample problems yourself. Which two drawings of the four on the right show the same object as the one on the left? There are always two and only two correct answers for each problem. Put an X under the two correct drawings.

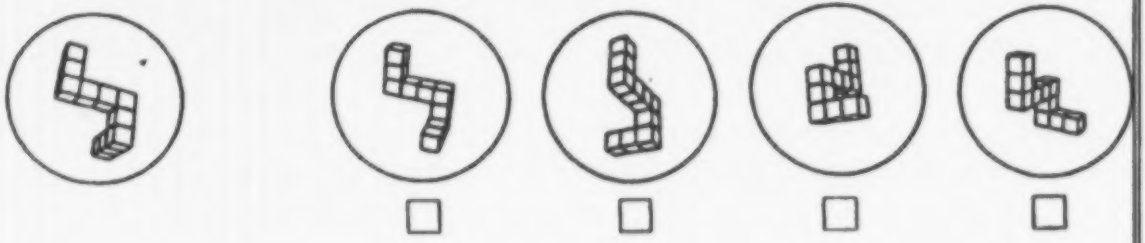
1.



2.



3.



Answers: 1. first and second drawings are correct
2. first and third drawings are correct
3. second and third drawings are correct

This test has two parts. You will have 5 minutes for each of the two parts. Each part has two pages. When you have finished Part I, STOP. Please do not go on to Part 2 until you are asked to do so. Remember: There are always two and only two correct answers for each item.

Work as quickly as you can without sacrificing accuracy. Your score on this test will reflect both the correct and incorrect responses. Therefore, it will not be to your advantage to guess unless you have some idea which choice is correct.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

Figure 1 (continued)

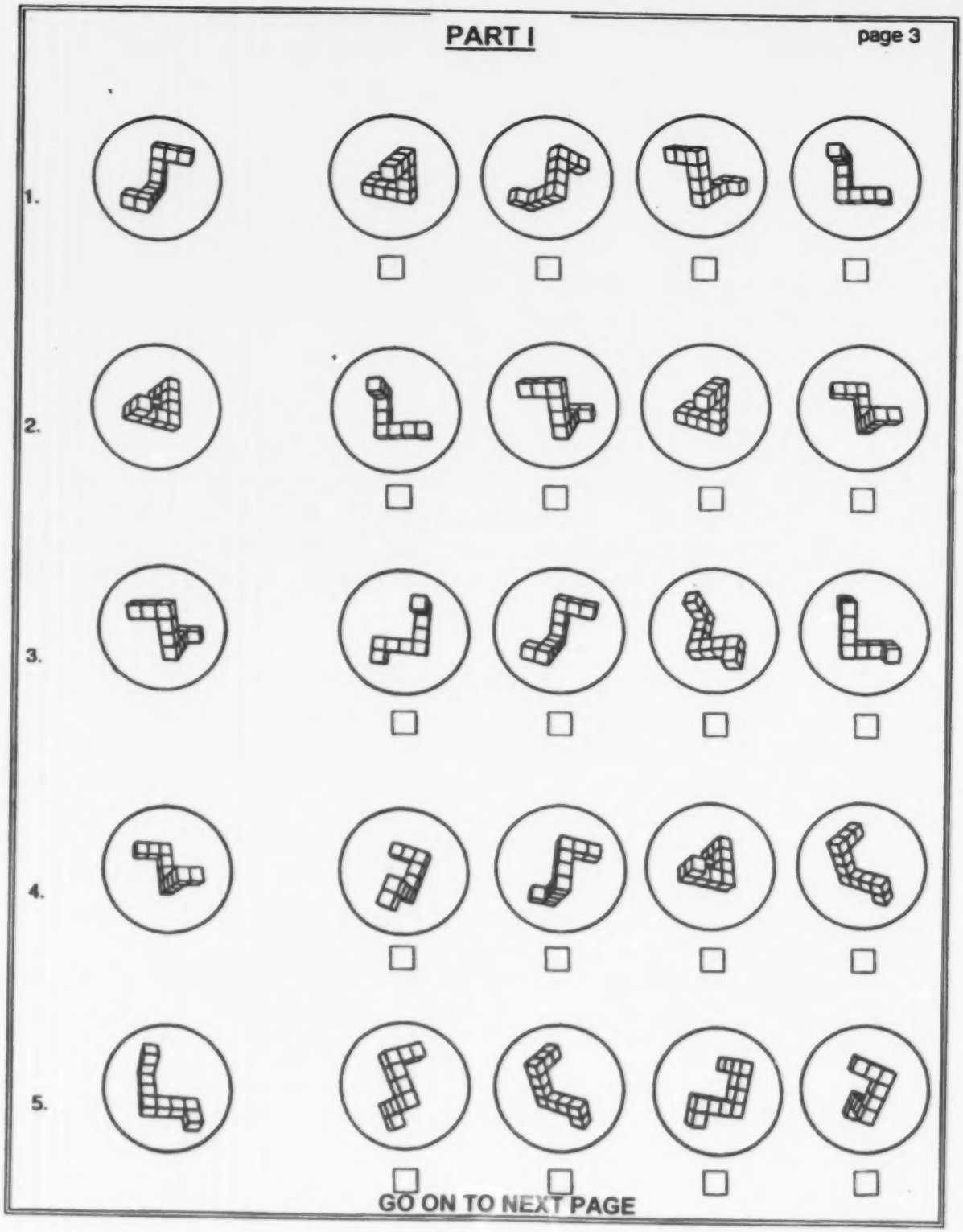
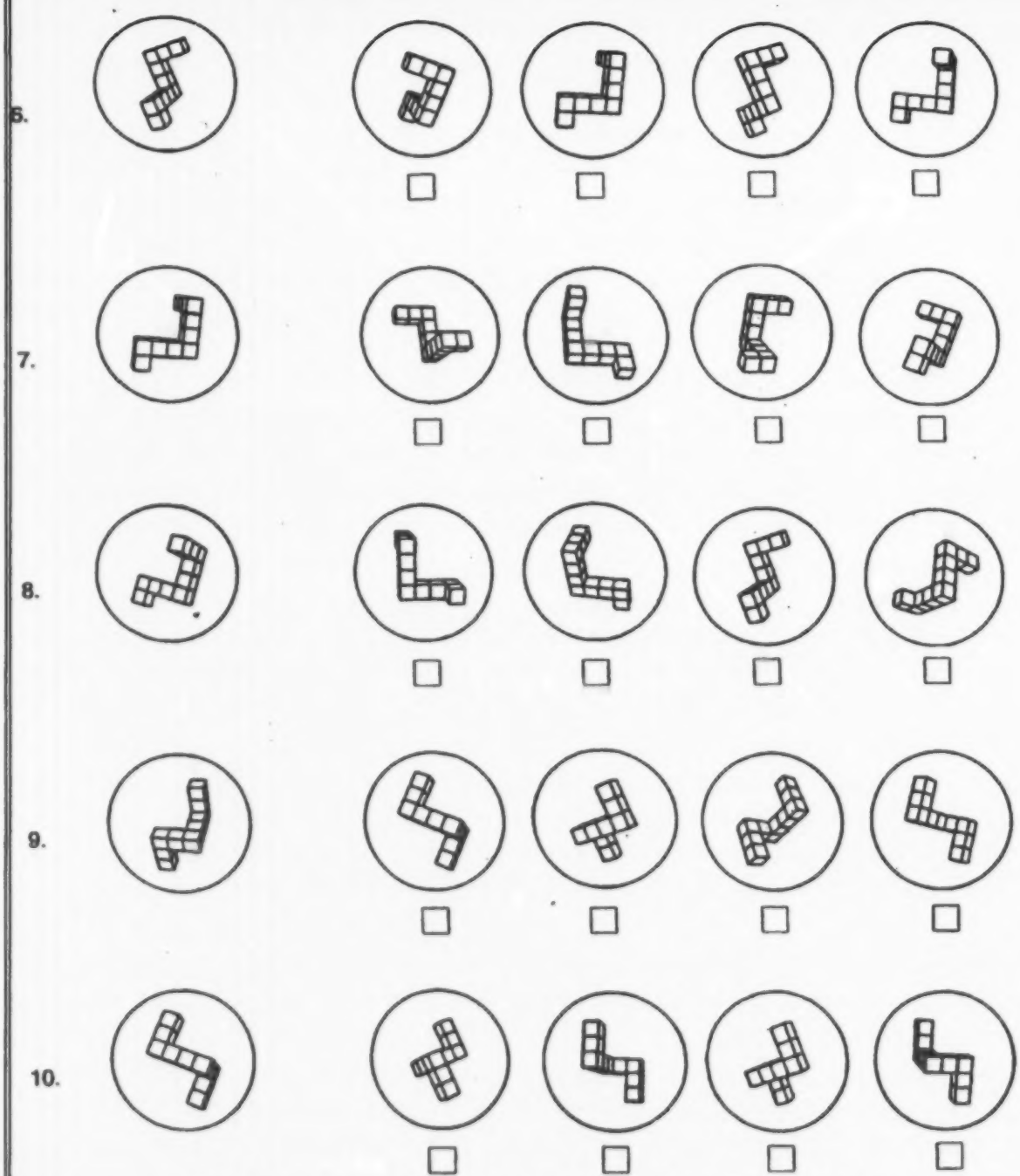


Figure 1 (continued)



DO NOT TURN THIS PAGE UNTO ASKED TO DO SO. STOP

Figure 1 (continued)

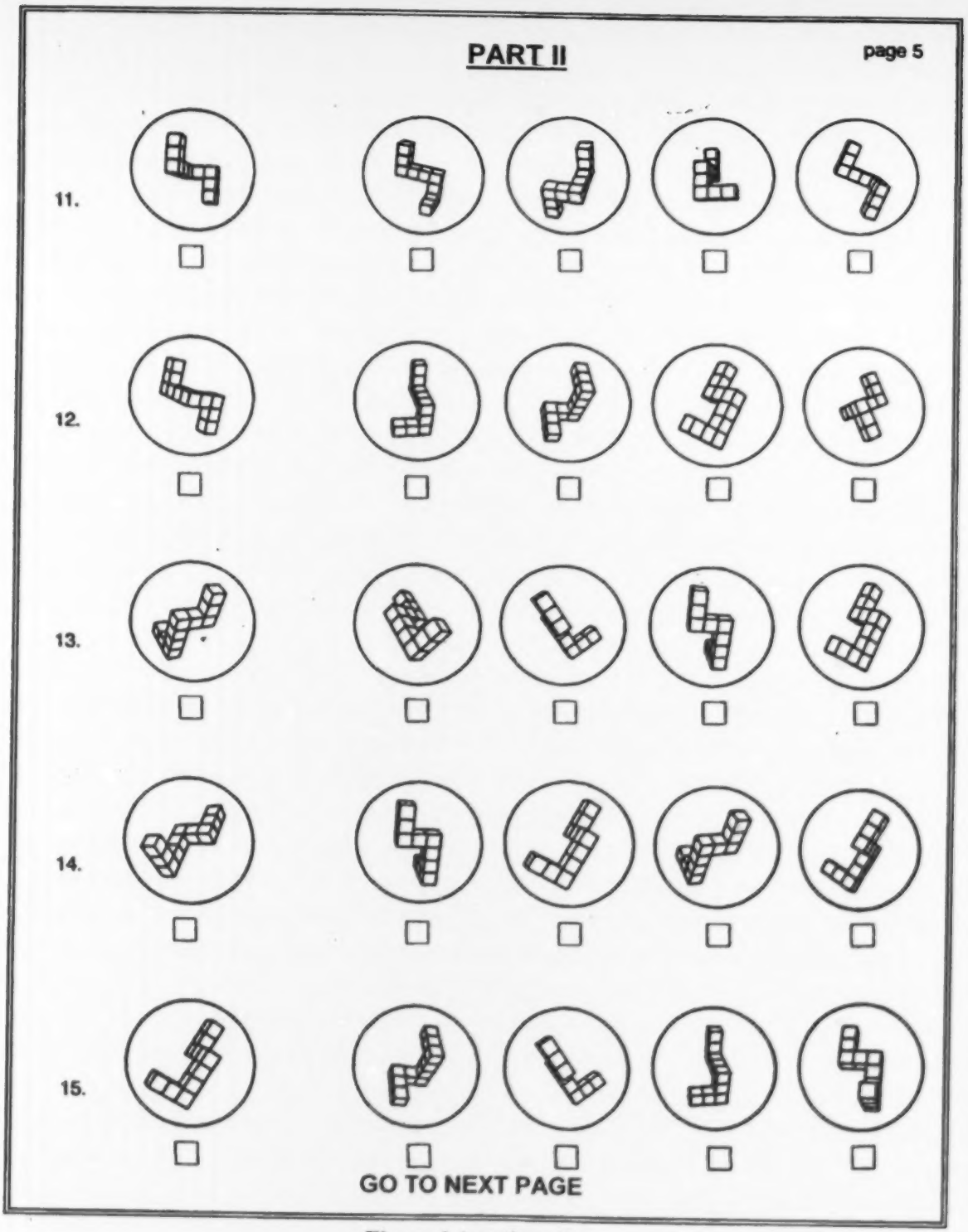


Figure 1 (continued)

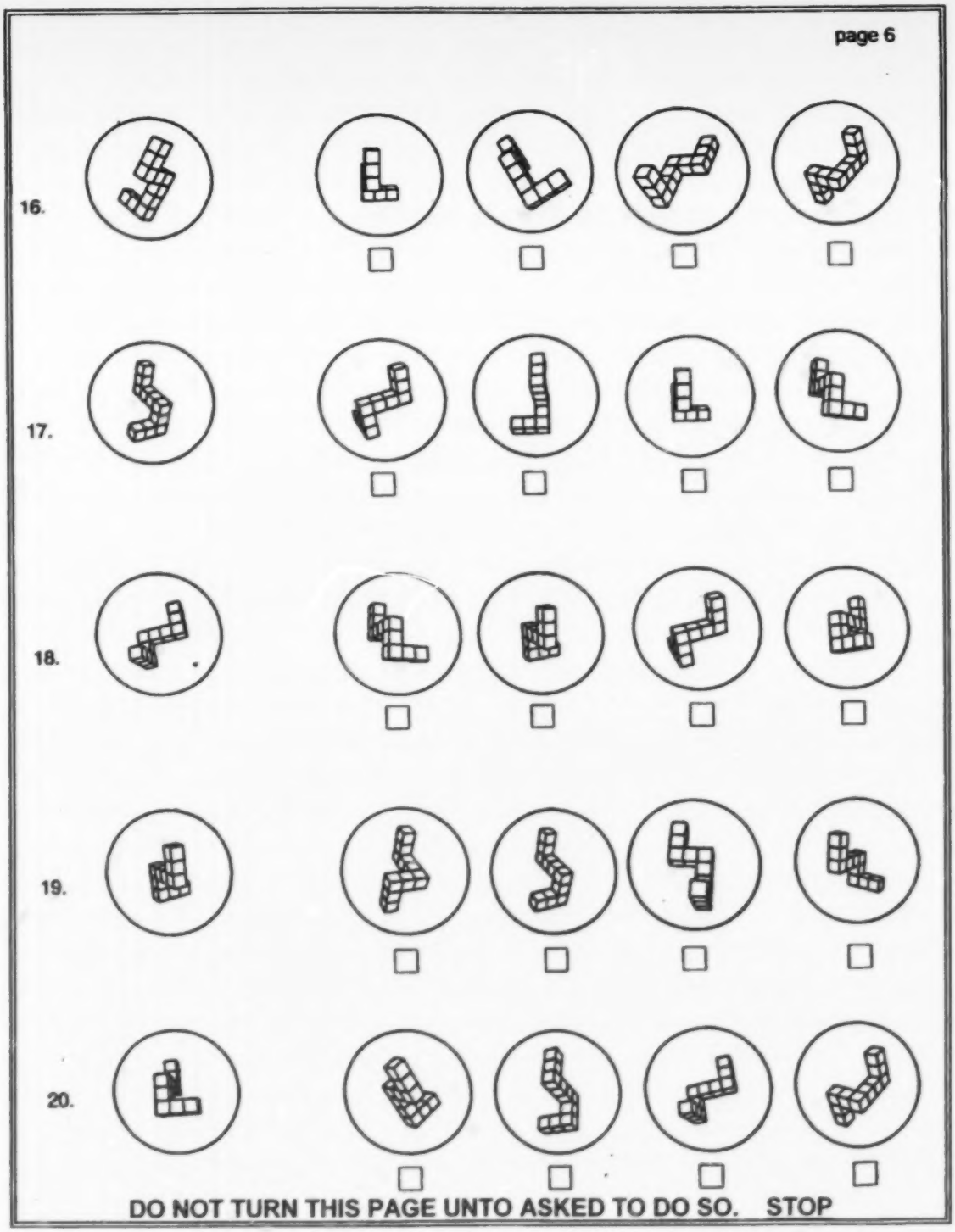


Figure 1 (continued)

PART III: Questionnaire of Mental Rotations Experiences

Please fill out this questionnaire to the best of your ability. Your answers must be honest responses to these statements. I appreciate the time and effort you take on completing it. You will remain anonymous. No one will ever know how you responded. There are 4 sections.

SECTION 1: Personal Background

1. Age____
2. Grade_____
3. Gender (circle one): Male Female
4. Ethnic background (circle one):
   Caucasian (White) African-American Hispanic-American Asian-American
   Middle Eastern-American Other or Mixed:_____
5. Fill in your letter or numerical grades for the following subjects:
   English____ Math_____ Science_____ Social Studies_____ Art_____

SECTION 2: Comparing Your Primary vs. Secondary Education

Directions: Using the (6) six-point scale, please circle a number in each column, which most accurately reflects how often you did these activities in the past (your childhood and middle school years) and how often you do them now.

1=never 2=rarely 3=occasionally 4=often 5=a great deal 6= all the time

Playing with Toys:	*In the Past*						*Now*					
1. Erector Sets	1	2	3	4	5	6	1	2	3	4	5	6
2. Building blocks	1	2	3	4	5	6	1	2	3	4	5	6
3. Legos	1	2	3	4	5	6	1	2	3	4	5	6
4. Puzzles	1	2	3	4	5	6	1	2	3	4	5	6
5. Other building toys	1	2	3	4	5	6	1	2	3	4	5	6
6. Video games	1	2	3	4	5	6	1	2	3	4	5	6
7. Model-making												
Extracurricular Activities:												
8. Art Museum visits	1	2	3	4	5	6	1	2	3	4	5	6
9. Art classes	1	2	3	4	5	6	1	2	3	4	5	6
10.Sports/ Physical Activities	1	2	3	4	5	6	1	2	3	4	5	6

GO TO THE NEXT PAGE

Figure 2: Designed by the researcher and *Section 3* highly modified by the researcher from a questionnaire by Peters, Laeng, Latham, Jackson, Zaiyouna, & Richardson (1995).

SECTION 3: Critiquing of Personal Performance **page 8**

For each of the eight sections below, please check the best statement that describes the thought processes and strategies you used while performing the test. *

1. **Use of Mental Rotation**
   - __ I ***rotated the whole figure*** in my mind when making the comparison.
   - __ I ***rotated a section of the figure*** in my mind when making the comparison.
   - __ I am not sure how I did it.
   - __ Other (explain)_____

2. **Verbal or Visual Thinking**
   - __ I thought through the steps ***verbally*** in my mind (i.e. "two cubes up and three down")
   - __ I relied mainly on ***visualizing*** the figures and did not talk myself through the steps.

3. **Use of Body Movements**
   - __ I used ***movements*** of my finger, hand and/or pencil to help me with the task.
   - __ I ***did not use movements*** of my finger, hand and/or pencil to help me with the task.

4. **Procedure**
   - __ I ***scanned*** the options for the most likely match and then made my choices.
   - __ I went through the options ***systematically***, trying the first, then the second etc.
   - __ I went through the options in a ***haphazard*** nonsystematic way.

5. **Comparing to the Target Figure**
   - __ I always compared the ***all the options*** to the target figure before making a match.
   - __ Once I found the match, I ***didn't compare the rest of the options*** to the match.
   - __ I used both methods at different times to make a match.

6. **Personal Approach**
   - __ I developed ***a specific approach*** to solve all the problems.
   - __ I tried ***various approaches*** to solve the problems.
   - __ I had no specific approach.

7. **Personal Concern**
   - __ I was more concerned with getting ***all of the answers completed***.
   - __ I was more concerned with getting ***the correct answers***.
   - __ I was equally concerned with getting ***the correct answers and completing the test***.
   - __ I ***did not care*** how I did.

8. **Determining My Confidence Level and Checking My Work**
   - __ I ***was confident*** of my answers and ***did*** check them before I moved to the next problem.
   - __ I ***was confident*** of my answers and ***did not*** check them before I moved to the next problem
   - __ I was ***vaguely confident*** of my answers and ***did*** check them before I moved to the next problem.
   - __ I was ***vaguely confident*** of my answers and ***did not*** check them before I moved to the next problem.
   - __ I was ***not confident*** of my answers and ***did*** check them before I moved to the next problem.
   - __ I was ***not confident*** of my answers and ***did not*** check them before I moved to the next problem.

*This section was originally designed by Peters, Laeng, Latham, Jackson, Zaiyouna, & Richardson (1995) and was highly modified.

SECTION 4: Overall Evaluation

How would you rate the Mental Rotations Test on a scale from 1-6, from 1=easy to 6=impossible.

Please circle one:

1 = very easy **2** = moderately easy **3** = neither easy nor impossible **4** = difficult **5** = very difficult **6** = impossible

Figure 2 (Continued)

items and their correct choices, and three examples with the correct answers below them. The 20 test items (10 items in each problem part) were divided into five sets of four items. Each item had a criterion figure, which was ten connecting cubes, and four corresponding figures (the choices or distracters, were rotated, mirror-images of the criterion or other structures.

College students were given six minutes (three minutes for each problem part) (Vandenberg and Kuse, 1978). If a test retest were desired, then the time limit was ten minutes (five minutes for each part). Because much testing had been done with college level students, the researcher felt the six-minute total time for the test was not enough time for a younger population, high school students. Therefore, the time limit of the test was changed to 10 minutes (five minutes for each part), as used in the test retest procedures. Because no information was provided as to how long to spend on the sample problem part, five minutes was allotted for this. Because no information was provided as to how long to spend on the break between Part I and Part II, one minute was allotted for this. The total time for the MRT was 16 minutes and five minutes to complete the questionnaire. The total time to complete the booklet was 21 minutes. The test was modified in a pilot study as described in the Procedure section and in Appendix A for its results.

The test can be scored three ways. The first method of scoring was to give two credits for a line with both choices correct, none if one choice was incorrect, but other one was correct, or if both were incorrect. If only one choice were selected, one point was given. The highest possible score on the test with this method of scoring was 40 as suggested in the "Answer Key for Mental Rotations Test" from Behavioral Measurement Data Base Services, where the researcher bought the test and by Vandenberg and Kuse (1978).

A second way of scoring was to give one point for each correct line (*scoring by line*) (Vandenberg and Kuse, 1978; Peters et al., 1995; Voyer, Voyer, and Bryden, 1995). This

eliminated the chance for the test taker to guess a correct answer. If one item on the line were wrong, the whole line was wrong. The highest possible score on the test with this method of scoring was 20.

A third possible way of scoring was to give one point for each correct answer (*scoring by item*) with the highest possible score of 40. However, this method of scoring gives more credit for guessing. "The reduced sex difference when it is scored this way may be a consequence of women's guessing more often than men (Voyer, Voyer, and Bryden, 1995, p. 259).

This study used the *scoring by line* method to determine the results. Because no information was given about what was a "good" score on this test, it was determined by the test scores of the classes.

The test was straightforward and objective. An answer was either correct or incorrect. The researcher scored all the tests.

In the original test booklet at the top of the first page, the participant filled in his/her name and the test date on the lines provided. Because the students' names had to be anonymous in this study, this information was eliminated and replaced with lines for the test date, and the participant's school, class type, grade, and sex. The class type was used for Hypothesis 1 and Hypothesis 2.

The reliability of the test was satisfactory, using the Kuder-Richardson reliability coefficient (N = 3268)=.88 (Wilson, Defries, McClearn, Vandenberg, Johnson and Rashad, 1975) with a sample of ages fourteen years old or older. The test-retest reliability coefficient was (N =336) =.83 after an interval of one year or more (Vandenberg and Kuse, 1978).

In comparing this test to four other tests of spatial ability there may be concurrent validity in the test because "the split-half reliabilities corrected by the Spearman-Brown formulas were .79,

.77, .69, and .78 respectively, suggesting that all four tests are comparable" (Vandenberg and Kuse, 1978, p. 601). Also, concurrent validity may ensue in the test because it was correlated to other tests of spatial abilities, where the construct validity of other spatial tests was high (Eliot and McWhinnie, 1990; Vandenberg and Kuse, 1978; Baker, 1990). It was difficult to test the construct validity, the spatial ability of mental rotations. The items on the test may have had item validity because they were using a score to measure the rotation of three-dimensional objects on a two-dimensional surface. Research has found that "There are no difficulties in identifying this as a test of spatial abilities" (Peters et al., 1995, p. 40). Sorby (1999), believed the MRT assesses "a person's skill in visualizing rotated solids" (Sorby, 1999, p. 25). Much research has cited this test or redrawn versions of it (Baker, 1990; Sorby, 1999; Holliday-Darr, 2000; Peters et al., 1995; Moody, 1998; Voyer, Voyer, and Bryden, 1995; Ozer, (1987).

The test was extremely easy to administer. The written instructions to take the test were straightforward and easy to follow. The test was short. The whole test was given at one time, and no posttest was required. Procedures for administering the test were given below. The test was given prior to the questionnaire because *Section 4* of the questionnaire asked students to rate their perceived difficulty of the test.

QUESTIONNAIRE

The "Questionnaire of Mental Rotations Experiences", Part III of the test, presented in Figure 2, was a self-report questionnaire with structured items. It was designed to provide information about the participant's age, gender, ethnic background, academic performance, past and present (doing now) visual-spatial activities, strategies used while performing the test, and ease of taking the test. It was derived from a review of the literature and highly modified from a questionnaire used by Peters et al. (1995).

The five-minute questionnaire, found on the last two pages of the test booklet, contained four sections. *Section 1*, composed of five items, asked for the student's age, grade, gender, ethnic background, and academic performance (Hypothesis 3 on gender and Hypothesis 5 on academic performance). *Section 2*, composed of 10 items, used a rating scale of 1=never, 2=rarely, 3=occasionally, 4=often, and 5=a great deal, and 6=all the time, asking subjects to rate the frequency with which they played with certain types of three-dimensional toys and activities performed outside of school in the past and now. These activities may have influenced their spatial ability. In the "Now" part, students indicted if they were presently taking art classes in school or outside of school. This was important because it took into account those students in non-art classes who were taking art classes in school. This section was used to see if there was a correlation between the MRT scores and activity scores in the past and now (Hypothesis 4). *Section 3*, composed of eight items, asked subjects about the strategies they used while performing the MRT: use of mental rotation (rotated the whole figure or a section of the figure); visual or verbal thinking (thought through the steps verbally by saying something like "two cubes up and three down or visualizing the figures and not talking through the steps); use of body movements (did or did not use fingers, hands, or pencil to help with the task) (Hypothesis 7). *Section 3* also asked strategies about their procedure, comparing to the target figure, personal approach, personal concern, determining their confidence level, and checking their work. It was highly modified from a questionnaire by Peters et al. (1995). *Section 4* asked students to rate the ease of taking the MRT by using a rating scale of 1=very easy, 2= moderately easy, 3=neither easy nor impossible, 4=difficult, 5=very difficult, and 6=impossible. This section was used to see if ease of taking the test correlated to performance on the MRT (Hypothesis 6).

MATERIALS/APPARATUS

Each student used a pencil with an eraser and an eight-page test booklet of comprised of four parts: the MRT test (the sample problem section, Part I, and Part II) and the Questionnaire (Part III).

PROCEDURE

Before beginning the study, a pilot study was conducted with a modified version of the administration of the MRT; the test items did not change (see Appendix). The time limit, procedures, and scoring of the test were slightly altered to allow for maximum understanding of mental rotations. Rather than the time limit being 10 minutes for the two problem sections, there was no time limit or any breaks. This allowed the participants to complete the test without feeling the pressure of any time constraints and to focus on finding the correct answers. They all completed the test at their own pace. The test was also modified from three parts to two parts: the first part, the sample problems, flowed directly into the second part, the 20 test items and the questionnaire. Also, the information at the top of the first page of the booklet was changed. The participant filled in the test date, and school, class, grade, and sex.

These modifications may have affected the reliability of the test. The pilot study was done in this manner to determine if high school students were capable of performing this type of test. It was determined that students were able to complete and understand the test booklet. The results of the pilot study are in the Appendix.

After the pilot study was administered, the teachers were contacted; they granted their verbal permission to administer the test and questionnaire to their students. They approached the principal and received his verbal consent.

Next, data gathering was done during a regularly scheduled class. It began with the examiner handing each student a pencil and the test booklet face down. When every one had received the materials, the examiner said to the students, "You may turn the test booklet over. Please fill out the information at the top of page 1. (Pause for students to fill out the top of the page.) This is a timed test, which will take you about 21 minutes to complete. The four parts of the test are each five minutes: a sample problem part, then Part I with 10 test items, then Part II with another 10 test items, and finally a questionnaire. You will have a one-minute break between Part II and Part III. You will start and stop each part when I say so. There will be no talking during the break. Do not be upset if you cannot finish the test. This is normal. Let's look at the sample problem part together." Then, the examiner read the problem part with the students. At the beginning of Part I, Part II, and the questionnaire the examiner said, "You may turn the page and begin", "Stop", and gave a one-minute break between Part I and Part II. At the end of the test the examiner said, "I thank you for your time." Donuts were handed out to thank students for their participation in the study.

PROCEDURE FOR DATA ANALYSIS

Data were processed by SPSS Student Version 11.0 for Windows (SPSS Inc., 2001). The data analysis was done with a *t*-test, a one way ANOVA, a Pearson *r*, a Tukey HSD test, or a Chi Square test. The level of significance to confirm the hypotheses was p=.05. The data was interpreted by supporting or not supporting each hypothesis:

Hypothesis 1: Art and Non-Art Classes

Art classes score higher on the MRT than non-art classes. A non-matched *t*-test computed these findings.

Hypothesis 2: Comparison of Class Types

The following hypotheses compare MRT performance and class type:

a. Sculpture classes have significantly higher scores on the MRT than Drawing and Painting classes.

b. Drawing and Painting classes have significantly higher scores on the MRT than Studio Art Foundation classes.

c. Studio Art Foundation classes have significantly higher scores on the MRT than the Social Studies classes and Psychology classes.

A oneway ANOVA computed all of these findings.

Hypothesis 3: Gender

a. Males score significantly higher on the MRT than females. The scores were sorted out and tallied by gender to compare the mean scores for females and males. This hypothesis was tested using a non-matched *t*-test.

Hypothesis 4: Visual-Spatial Activities

a. Students who score high on the MRT also score high on the items in "In the Past" part of *Section 2* of the questionnaire. There is a positive correlation between the MRT scores and activities in which students did in the past. A Pearson *r* was used to determine the degree of positive correlation between the MRT scores and activities in which students did in the past.

b. Males who score high on the MRT also score high on the items in "In the Past" part of *Section 2* of the questionnaire. There is a positive correlation between the MRT scores and activities males did in the past. A non-matched *t*-test computed these findings.

c. Students who score high on the MRT also score high on the items in the "Now" part of *Section 2* of the questionnaire. There is a positive correlation between the MRT scores and activities students are doing now. A Pearson *r* computed these findings.

Hypothesis 5: Strong Academic Performance per Discipline

Students whose state their best academic subject (written either numerically or with a letter grade) in school this year, is in art, math, or science score higher on the MRT than those students whose best grade is in English or Social Studies. A oneway ANOVA computed these findings.

Hypothesis 6: Ease of Taking the Test

There is a positive correlation between a student's MRT score and the ease of taking the test. This hypothesis was tested using a Pearson *r*.

Hypothesis 7: Strategies Used to Solve Problems

Mental Rotation Strategy:

a. Students who mentally rotate the whole figure to solve the problems score significantly higher on the MRT than students who rotate a section of the figure. A oneway ANOVA computed these findings.

b. More males than females mentally rotate the whole figure to solve the problems on the MRT. A chi square test computed these findings.

Visual and Verbal Strategy:

c. Students who use a nonverbal, visual approach (abstract, mental images), score higher on the MRT than students who think through the steps verbally in their mind. A oneway ANOVA computed these findings.

d. More males than females use a nonverbal strategy to solve the MRT. Females use a verbal strategy more than males. A chi square test computed these findings.

Use of Body Movement Strategy:

e. Students who do not use movements of their fingers, hand and/or pencil to help solve the problems on the MRT score higher than students who use movements of their fingers, hand and/or pencil to help solve the problems on the MRT. A non-matched *t*-test computed these findings.

f. More females than males use movements of their fingers, hand, and/or pencil to help solve the problems on the MRT. A chi square test computed these findings.

DELIMITATIONS

A delimitation of the study (what the researcher could control) was choosing a high school sample from the accessible population, art and non-art students. Another delimitation of the study was using only the MRT to test for mental rotations, a subset of spatial ability.

LIMITATIONS (THREATS TO EXTERNAL AND INTERNAL VALIDTY)

The limitations of the study (what was beyond the researcher's control) were the limited amount of construct and content validity of the test, the sampling method, and the administration of the test. There was much research confirming the reliability of the test; however, little confirmed the construct validity of the test, except that it had been used in and adapted by many studies on mental rotations, as mentioned above.

THREATS TO EXTERNAL VALIDITY

The external validity of this study was threatened due to selection-treatment interaction because of the non-randomization of the sample. The target population, which was all high school students in art classes and social studies classes in the United States, was different from

the accessible population. It was impossible to do a random sampling of this population because of time and limited resources. Because purposive sampling of intact classes formed the selection of this population, the results could not be generalized to all of the country's high school population. This type of population was too skewed. Its ethnic composition and socioeconomic background was too homogenous. It was predominately a white, middle class to wealthy community.

Since the test could not be administered to all of the classes at once, treatment diffusion may have resulted; students may have shared information about the test with each other between classes, biasing the test scores. Interaction of history and treatment effects could have occurred in one social studies class because the teacher was absent and a substitute teacher was in his place.

The administration of the test was affected by the cooperating teachers' non-verbal attitudes and body cues, which were positive towards the research. Also, experimenter effects and experimenter bias occurred because the researcher's conscious or unconscious actions may have affected the participants' performance, by being too overly enthusiastic about the test while going over the instructions and sample problem part of the test.

THREATS TO INTERNAL VALIDITY

The internal validity was threatened due to differential selection of the participants and sampling bias. Mental rotations may have been dependent on the spatial ability of the individual. Students in the non-sculpture classes may have had or were presently engaged in art experiences, where they created a fair amount of three-dimensional art, which may have biased their test scores, causing them to receive a higher score on the MRT. Their spatial ability may be better because of these art experiences. It was possible that some students had attended different

schools before entering the high school and had different art experiences in their previous schools, which may have biased the test results. *Section 2* of the questionnaire was designed to identify these art experiences, especially those students in the non-art classes. Although participants were the same age, according to Lowenthal (1987), they may have been at different developmental levels, which may have altered the test results.

The number of participants in the study (n= 186) was not a large sample; each group varied in size. The grade levels of the students were slightly different, which may have affected the study [i.e. sculpture classes in grades 9-12 (n=42); Studio Art Foundation classes in grades 9-12 (n=44); Drawing and Painting classes in grades 10-12 (n=42); Social Studies classes in grade 10 (n=22); and three Psychology classes in grades 11-12 (n=63)]. The number of participants in the study decreased slightly because four of the seven students who had taken the test as part of the pilot study were enrolled in one of the classes being tested; their test could only be counted once.

The researcher's inexperience posed limitations in the study by possibly not analyzing the data objectively or correctly. Since this is the researcher's first research study, mistakes could have been made that an experienced researcher would not make.

TIME SCHEDULE FOR THE RESEARCH STUDY

The research part of the study was conducted from January to February.

January and February:

- January 6-10: Made an appointment to see the administration at the high school, and received approval to conduct the study.
- January 13-February 14: Conducted the study. Because of conflicting class schedules, a snow day, and the workload of each class, it took a total of ten days to conduct the study:

two days with the social studies classes; three days with the psychology classes; five days with the art classes.

BUDGET

$ 20.00 test

.00 free Xeroxing for test booklet

2.00 for pencils

62.27 donuts for classes

19.20 gas for car

$103.47 TOTAL EXPENSES

IV. RESULTS

PURPOSE

The purpose of this chapter is to present the results of the study.

RESULTS OF OBJECTIVE MEASURES

Students (N=186) were given the MRT and a questionnaire in order to compare their mental rotation performance on art ability, gender, academic performance, visual-spatial activities, strategies used while performing the test, and the ease of taking the test. The method of *scoring by line* on the MRT was used for all of the comparisons in this study because this type of scoring hopefully eliminated the chance for test taker to guess a correct answer. The level of significance to confirm the hypotheses was p=.05. The results of each hypothesis are presented below.

HYPOTHESES

Hypothesis 1: Art and Non-Art Classes

Art classes score higher on the MRT than non-art classes. This hypothesis was not supported. A non-matched t-test was computed using art classes' and non-art classes' scores. The results indicated that there were no significant differences in the MRT scores between the art and non-art classes, $t(184) = 1.687$, $p = .093$ (see Table 2).

Table 2: MRT Performance and Art and Non-art Classes. n= number of students in the classes.

Class Type	*n*	*M*	*SD*
Non-art Classes	85	11.5765	5.5343
Art Classes	101	10.1782	5.7121

Hypothesis 2: Comparison of Class Types

The following hypotheses compare MRT performance and class type. The results are listed after the hypotheses:

a. Sculpture classes have significantly higher scores on the MRT than Drawing and Painting classes.

b. Drawing and Painting classes have significantly higher scores on the MRT than Studio Art Foundation classes.

c. Studio Art Foundation classes have significantly higher scores on the MRT than the Social Studies class and Psychology classes.

These hypotheses were not supported. Although, using a oneway ANOVA, MRT scores were found to be significantly different across the five different class types, $F(4,181) = 3.524$, $p=.009$, it was not in the order which was hypothesized (see Table 3). The order of the five different class types from highest to lowest mean score was Social Studies, Sculpture, Psychology, Drawing and Painting, and Studio Art Foundation (see Table 3). A Tukey HSD test was performed to assess pairwise differences on the MRT scores by these class types. Significant results found that the Social Studies class performed significantly better than Studio Art Foundation classes on the MRT, $p=.008$. Also, Sculpture classes had significantly higher scores on the MRT as compared to Studio Art Foundation classes, $p = .026$, which is in agreement with the hypothesis of the descending order of the MRT scores per class type. All other comparisons were not significantly different (see Table 3).

Hypothesis 3: Gender

Males score significantly higher on the MRT than females. This hypothesis was supported.

A non-matched *t*-test was computed using gender. Males scored significantly higher than females on the MRT, $t(184) = 6.184$, $p < .001$ (see Table 4).

Table 3: MRT Performance and Class Types with percentages of students who received a score of twenty or a score of less than 11 per class type. *n* = number of students in each class; *N* = total number of students.

Five Class Types	*n*	*% of N*	*M*	*SD*	*% scored 20*	*% scored < 11*
Social Studies	22	11.8%	13.1364	4.7639	9%	23%
Sculpture	42	22.6%	11.9048	5.4764	5%	40%
Psychology	63	33.9%	11.0317	5.7135	5%	52%
Drawing and Painting	26	14.0%	10.0000	5.9464	8%	62%
Studio Art Foundation	33	17.7%	8.01212	5.2545	0%	70%

Table 4: MRT Performance by Gender.

Gender	*n*	*M*	*SD*
Males	80	13.5125	5.5484
Females	106	8.7830	4.8541

Hypothesis 4: Visual-Spatial Activities

a. Students who score high on the MRT also score high on the items in "In the Past" part of *Section 2* of the questionnaire. There is a positive correlation between the MRT scores

and activities students did in the past. This hypothesis was supported. A Pearson *r* computed these findings. There was a significant, positive correlation between the MRT scores and activities which students did in the past, $r(173) = +.221$, $p = .003$. The higher a student scored on the MRT, the higher they scored on the items in "In the Past" part of *Section 2* of the questionnaire.

b. Males who score high on the MRT also score high on the items in "In the Past" part of *Section 2* of the questionnaire. There is a positive correlation between the MRT scores and activities males did in the past. This hypothesis was supported. A non-matched *t*-test computed these findings. There was a significant difference in how much "In the Past" visual-spatial activities males and females reported and their MRT scores. Males scores were significantly higher than females on "In the Past" section of the questionnaire, $t(173) = 2.909$, $p = .004$.

c. Students who score high on the MRT also score high on the items in the "Now" part of *Section 2* of the questionnaire. There is a positive correlation between the MRT scores and activities students are doing now. This hypothesis was not supported. A Pearson *r* computed these findings. There was no significant correlation between the MRT scores and activities, which students are doing now, $r(167) = +.068$, $p = .380$.

Hypothesis 5: Strong Academic Performance per Discipline

Students whose state their best academic subject (written either numerically or with a letter grade) during the school year, is in art, math, or science score higher on the MRT than those students whose best grade is in English or Social Studies. This hypothesis was not supported. Using a oneway ANOVA, no significant differences were found on MRT performance based on what students reported as their best academic subject, $F(4,104) = .833$,

$p = .507$. The mean (M) for each class type varied slightly: science with $M = 12.3500$, social studies with $M = 12.0000$, math with $M = 11.2727$, art with $M = 10.5455$, and English with $M = 8.7778$. Science had the highest mean score and English had the lowest mean score.

Hypothesis 6: Ease of Taking the Test

There is a positive correlation between a student's MRT score and the ease of taking the test. This hypothesis was supported. A Pearson r computed these findings. As the MRT scores increased, the perceived ease of taking the test increased, $r(160) = +.472$, $p < .001$.

Hypothesis 7: Strategies Used to Solve Problems

Mental Rotation Strategy:

a. Students who mentally rotate the whole figure to solve the problems score significantly higher on the MRT than students who rotate a section of the figure. This hypothesis was supported. A oneway ANOVA was used to compute these findings. There was a significant difference in the MRT scores based on the rotation strategy students used to solve the problems, $F(4, 176) = 8.28$, $p < .001$. Students who reported mentally rotating the whole figure in their minds to solve the problems scored higher on the MRT than either students who reported mentally rotating a section of the figure, $p < .001$, or those students who were not sure how they solved the problems, $p < .001$ (see Table 5).
b. More males than females mentally rotate the whole figure to solve the problems on the MRT. Using a chi square test, this hypothesis was not supported, $X^2 (4) = 5.865$, $p = .209$ (see Table 6). Males and females did not adopt significantly different mental rotation strategies to solve the problems. However, it is interesting to note that a higher

percentage of females more than males, 18.4% and 9% respectively, stated they mentally rotated a section of the figure, although this result was not significant (see Table 6).

Table 5: Mental Rotation Strategy and Performance on the MRT.

Rotation Strategy	*n*	*M*	*SD*
Rotated Whole Figure	117	12.4103	5.2852
Unsure of Rotation Strategy	29	7.5862	.2815
Rotated Section of Figure	26	7.5385	4.5627

Table 6: Frequency of Mental Rotation Strategy by Gender.

Type of Strategy	Males	Females
Rotated Whole Figure	69.2%	61.2%
Unsure of Rotation Strategy	14.1%	17.5%
Rotated Section of Figure	9%	18.4%

Visual and Verbal Strategy:

c. Students who use a nonverbal, visual approach (abstract, mental images), score higher on the MRT than students who think through the steps verbally in their mind. This hypothesis was supported. A oneway ANOVA computed these findings. There was a significant difference in the MRT scores based on the visual or verbal strategy students used to solve the problems, $F(2, 178) = 11.697$, $p < .001$. Students who stated they used a visual strategy to solve the problems on the MRT scored higher than those students who used a verbal strategy to solve the problems, $p < .001$. Yet, those students who used both

visual and verbal strategies to solve the problems on the MRT scored significantly higher on the MRT than those students who used only the verbal strategy to solve the problems, $p < .014$ (see Table 7).

Table 7: Visual and Verbal Strategy and Performance on the MRT.

Type of Strategy	*n*	*M*	*SD*
Visual and Verbal	10	13.1000	4.817
Visual	116	11.9655	5.5340
Verbal	55	7.9455	4.8702

d. More males than females use a nonverbal strategy to solve the problems on the MRT. Females use a verbal strategy more than males. Using a chi square test, this hypothesis was not supported. For males and females the visual approach was significantly more dominant than the verbal approach, however, the visual approach was stronger for males, $X^2(2) = 12.979, p = .002$ (see Table 8). In both cases a majority of males and females, 78.7% and 53.8%, respectively, used a visual approach to help solve the problems on the MRT. However, it is interesting to note that a higher percentage of females more than males, 40.6% and 16%, respectively, did report using a verbal strategy to help solve the problems on the MRT, although this result was insignificant (see Table 8).

Use of Body Movements Strategy:

e. Students who do not use movements of their fingers, hand, and/or pencil to help solve the problems on the MRT score higher than students who use movements of their fingers, hand, and/or pencil to help solve the problems on the MRT. A non-matched *t*-test computed these findings. This hypothesis was not supported. There was no significant

correlation on test scores based on movement strategies used, $t(177) = -1.472$, $p = .143$ (see Table 9).

Table 8: Frequency of Visual and Verbal Strategy by Gender.

Type of Strategy	Males	Females
Visual	78.7%	53.8%
Verbal	16%	40.6%
Visual and Verbal	5.3%	5.7%

Table 9: Use of Body Movements and Performance on the MRT.

Type of Strategy	*n*	*M*	*SD*
No Body Movements	133	11.1805	5.6432
Used Body Movements	46	9.7609	5.6260

f. More females than males use movements of their fingers, hand, and/or pencil to help solve the problems on the MRT. Using a chi square test, this hypothesis was supported. In both cases a majority of males and females, 85.5% and 65.4%, respectively, did not use movements of their fingers, hand, and/or pencil to help solve the problems on the MRT (see table 4.10). However, a higher percentage of females more than males, 33.7% and 14.5%, respectively, did report using movements of their fingers, hand, and/or pencil to help solve the problems on the MRT, $X^2(2) = 9.463$, $p = .009$ (see Table 10).

Table 10: Frequency of Body Movement Strategy by Gender.

Type of Strategy	Males	Females
Used Body Movements	14.5%	33.7%
No Body Movements	85.5%	65.4%

SUBJECTIVE OBSERVATIONS

As the tests were being conducted, students wanted to know their scores. The researcher had corrected about half of them, when she began allowing the person to the right of the test taker to correct the test. This eliminated students from grading their tests and possibly falsifying their scores. In one case, a 12th grade student after learning his high score was seriously rethinking his college major. It made him realize he had spatial skills he did not know he possessed. Conversely, an art student, who was a good artist according to her teacher, scored low on this test. This test did not reflect her art ability; it may have predicted her spatial ability. A person may have good two-dimensional ability, yet poor three-dimensional ability. This verbal feedback provided insightful information as to the importance of spatial ability testing and training.

The questionnaire was a self-report instrument adopted from past studies and the researcher's ideas. A number of female students questioned *Section 2* of the questionnaire, saying it was sexist; there were many boy-type items, ie. Lego blocks, erector sets, etc., but no girl-type items such as building doll houses or performing interior design skills during play (rearranging doll furniture, their room, etc.)

A few students who were unable to finish the test reported that they would have done well on the test, if they were given more time; they had gotten quite a few of the answered questions correct. The timed test may have been unfair to those students who needed more time to

understand the test or felt too much pressure to do it in the allotted time; an untimed test may have helped them process the information on the test better and at a more leisurely pace. Some students were upset that they could not finish the test or go back to a section that they had left incomplete.

Some students found the test difficult and frustrating, while others felt it was easy. Classes' atmospheres varied when they were taking the test. When too much talking went on during the test, the students seemed to not take the task seriously. This happened in a class of mostly 9th graders. The Social Studies class had a substitute teacher, which was the student teacher; this class was the most serious of all. Possibly, the substitute teacher runs a strict no-nonsense class.

The Psychology classes were relatively serious during the test with some talking. However, they were the most insightful when we discussed the test and its implications afterwards. This may have been because this was a Psychology class, and the teacher felt the students had the opportunity to participate in a research study.

CONCLUSIONS

In conclusion, many different factors may have affected the results. Gender played an important role in predicting a student's MRT scores; males significantly outperformed females on the test. Also, students scored higher on the MRT if they participated in visual-spatial activities in the past. Taking this further, males' scores were significantly higher than females when reporting their visual-spatial activities in the past. In addition, specific strategies to solve the problems were consistent with higher test scores, such as the rotation of the whole figure not a section of the figure and a visual approach not a verbal approach. Finally, as the MRT scores increased, the perceived ease of taking the test increased.

Although there were no significant differences between the scores of art and non-art classes as a whole, the Social Studies class had significantly higher scores than Sculpture classes, and Sculpture classes had significantly higher scores than Studio Art Foundation classes. Also, no significant differences were found on MRT performance based on what students reported as their best academic subject, and the visual-spatial activities they performed in the present, or body movement strategy.

Three other interesting results developed from this study that was not part of the hypotheses. First, using a chi square test, there was a significant difference in the male/female ratio per class type, X^2 (4) = 11.167, p = .025. There were fewer males than females in the different class types; only Sculpture classes had a majority of males. This may have contributed to the Sculpture classes ranking second highest on the MRT. Although they may not have had as high an intelligent quotient as the Social Studies class, the Sculpture classes may have achieved this ranking because males are known to score higher on this test than females. Second, using a chi square test, there was no significant difference in the test scores between the different grade levels, X^2 (60) = 60.828, p = .446. Third, male drawing and painting students had the highest mean scores of all the groups; however, the female drawing and painting students had the lowest mean scores of all the groups, causing this class's mean score to be low. (see Table 11).

The following chapter, Discussion, Conclusions, and Recommendations examines these results in depth.

Table 11: MRT Performance by Class Type and Gender.

Class Type	Males		Females	
	(n)	***M***	**(n)**	***M***
Drawing and Painting	(9)	14.2222	(17)	7.0000
Social Studies	(10)	13.9000	(12)	12.5000
Psychology	(30)	13.7333	(33)	8.0606
Sculpture	(24)	12.9583	(18)	10.5000
Studio Art	(7)	11.5714	(26)	7.1932

V. DISCUSSION, CONCLUSIONS, & RECOMMENDATIONS

PURPOSE

The purpose of this chapter is to present an analysis and interpretation of the results of the study as well as present conclusions and recommendations for future research.

DISCUSSION

CONTRIBUTING FACTORS AND RECOMMENDATIONS

Many factors may have contributed to not supporting some of the hypotheses (H). H1, Art and Non-art classes, and H2, Comparison of Class Types, were not supported, possibly because of selection treatment-interaction: 1) the sample population of high school students was from a predominately white middle class to wealthy community, which was too homogenous as compared to the general population. Therefore, the results could not be generalized to the country's high school population; 2) a random sampling could not be done because of time, limited resources, and the small size of the classes would have limited the study to too few students. Purposive sampling of intact classes formed the selection of this population; all sculpture classes, of which there were not many, had to be used. Drawing and Painting classes, Studio Art Foundation classes, the Social Studies class, and the Psychology classes were chosen because of scheduling, the willingness of the teachers to participate in the study, and the classes provided the largest number of students available to the researcher. Math and science students may have been useful to test the hypotheses; however, the researcher did not personally know any math or science teachers.

The results of the study may have been affected because of differential selection of the participants, where the characteristics in the different class types were not the same. Of the 186 students, 57 % were females and 43% were males; the number of students by gender or by class

type was not the same. However, the Social Studies class had more females than males, 54.5% to 45.5% respectively, which should have given the class a low, mean score. Yet, this class scored significantly higher on the MRT, which does not support H1. This may have occurred for five reasons. First, this class type had the lowest percentage of students, (2%), with a score of 11 or below, and had the highest percentage of students, (9%), with a perfect score of 20. Second, this may have happened because this was the smallest class type, 11.8% of the total population (see Table 3). A sample size of fewer than 30 students is a questionable size to use; small samples may yield inaccurate results. Third, the Social Studies teacher told the researcher that this was an exceptionally bright class as compared to other Social Studies classes he had taught in his 32 years of teaching. Intelligence may be correlated to spatial ability. Fourth, these students may have had more spatially enriching experiences than the other class types. Fifth, 27% of these students reported that they math or science was their best academic subject; their mean score on the MRT was 15.8333, which was a higher mean score than the Social Studies class, 13.1364. Because the Social Studies class had the highest mean score on the MRT, art classes did not score higher than non-art classes. If the study were to eliminate the Social Studies class, the Sculpture classes had the next highest scores on the MRT.

The only result supporting H1 is that sculpture classes scored significantly higher on the MRT than Studio Art Foundation classes. Two possible factors may have contributed to the Studio Art Foundation classes' low performance on the test. First, the Studio Art Foundation classes had the smallest percentage of males to females in a class: 21.2% and 78.8% respectively. Females are known to score lower than males on this test. Second, no student had a perfect score of 20, and 61% of the students had a score of under 11, which was the highest

percentage of low scores in all of the class types (see Table 4.3). The other classes had some students with a score of 20 and had fewer students with scores under 11 (see Table 4.3).

Because the school was small, treatment diffusion did occur. Some students knew about the test from other students. Also, some students had classes in both art and non-art classes without the researcher's knowledge. Unfortunately, these students who had first taken the test in a non-art class were unable to take the test in their art class because pretest treatment interaction would have resulted; they may have done better on it because they were familiar with it contents. These students did not take the test again. This proved to be true when a female in the pilot study, who had scored a 21 on the test, took it again in her art class and scored a 38; this is a very large increase. When she was asked why she felt she did so much better the second time, she replied that she knew what to do. Her second test was not counted.

Because of the researcher's lack of foresight to find out in advance if any students were in more than one class being tested and the anonymity of the test takers, the scores of eight students could not be included in their appropriate art class, but had to be included in their non-art class. If the test is administered in future studies, it would be advisable to ask students prior to taking the test if they were in the other classes that were being tested, so their test scores could be included in their correct art classes.

The results for H4, Strong Academic Performance per Discipline, may be inaccurate because only 59% of the students chose one best academic subject. Many listed more than one best subject or refused to answer the item altogether.

Since the questionnaire was a self-report instrument adopted from past studies and the researcher's ideas, it could not be validated or proven to be reliable. However, some of the results from this questionnaire did agree with past research, which may give it some reliability

and validity. Yet, the results gathered from it should be thought of as reflective information, and not completely factual information. Possibly, future studies should use it to see if their results replicate this study and/or revise it to make it more standardized and clearer to the test taker.

The results supported H3a, but not H3b on visual-spatial activities because 1) the findings may have been affected by the directions for *Section 2* of the questionnaire, which may have been unclear; 2) students may have had a hard time rating these activities, causing them to not rate the items accurately, skewing the results; 3) the items in *Section 2* of the questionnaire may have been sexist because very few items in it were geared towards traditionally female type activities, such as building or designing interior spaces of dollhouses or other structures. If more of these types of items were in this section, the females' scores on the "In the Past" section may have been higher. Future studies may consider adding more "female type" activities to their questionnaire, asking about a participant's visual-spatial activities.

Two changes in the administration of the test may have affected the results of the study: the test's time limit and scoring method. Much research has used this test with college age students, where the total time for the test was six minutes. In this study the total test time was 10-minutes, giving more time to high school students. High school students are at a different developmental age than college students; the researcher felt high school students should be allowed more time because they were younger and less mature. This decision came about when some students in the pilot session felt they needed more time to take the test. Also, the scoring method of the test, *scoring by line*, was chosen over the other two methods because *scoring by item* would allow for too much guessing on the test. Too few students used the other method to cause different results from the *scoring by line* method.

Experimenter effects and experimenter bias may have occurred, affecting the participants' performance because of the researcher's conscious or unconscious actions, being too overly enthusiastic about the test while going over the instructions and sample problem part of the test.

RELATIONSHIP TO LITERATURE

Results of this study agreed and disagreed with the results found in the articles reviewed in Chapter II. Much research has compared MRT performance to art ability, gender, academic performance, visual-spatial activities, and strategies used while performing the test. Also, the time limit of the test may change the results of the study.

Art Ability. This study did not agree with the findings of past research on art ability. Non-art classes scored higher on the MRT than art classes. According to Ascher (1999-2000), artists have higher levels of mental rotation abilities than non-artists. In past research, strong relationships occurred between high spatial task performance, which consisted of mostly mental rotation tasks and certain artistic activities (drawing, mechanical drawing, jewelry making, and photography) and art courses (architecture, drafting, studio arts, and applied design) (Olsen, Eliot, and Hardy, 1998 cited in Ascher, 1999-2000). Eliot and Smith (1983), also found a strong correlation between spatial ability and success in academic areas such as mathematics, interior design, physics, technical drawings, woodwork, and engineering because they require "analytical visual skills" (Orde, 1997, p. 273).

Gender. The results of this study were consistent with past research on gender, where males scored higher than females in mental rotation (Kimura 1999; Masters 1998; Peters, Laeng Latham, Jackson, Zaiyouna, and Richardson, 1995; Masters and Sanders, 1993; Resnick, 1993; Vandenberg and Kuse, 1978; Baker, 1990; Holliday-Darr, Blasko, and Dwyer, 2000; Ascher, 1999-2000; Moody, 1998). Although Eliot and McWhinnie (1990), found that gender did not

affect the scores on spatial ability tests given to professional art students at an art college, this study found that gender influenced MRT performance at the high school level even in the art classes. However, Moody (1998), "believes investigating individual differences among subgroups of women is more important than investigation differences between men and women" and "future research should implement a treatment of providing spatial experiences to various women subgroups to see if spatial ability can be developed in certain of these subgroups" (p. 59).

Academic Performance. This study found no significant differences on MRT performance based on what students reported as their best academic subject; it did not agree with the articles in the literature review section on academic performance. Yet, comparing the mean scores on the MRT and students' best academic subjects reported, highest to lowest mean scores were science, social studies, math, art, and English. Science was the highest best subject in comparison to MRT performance, although this finding was not significant. This finding was in agreement with past research where there was a correlation between the sciences and MRT performance. Peters et. al (1995) found college students enrolled in Science programs (engineering, biological, and physical sciences) scored higher than students enrolled in arts programs (social sciences, arts, and humanities).

Eliot and Smith (1983), Shepard and Meltzer (1971), and Baker (1990) associated a strong correlation between spatial ability and success in academic areas such as mathematics, design, architecture, engineering, physical sciences, technical drawings, and woodwork because they require "analytical visual skills" (Eliot and Smith, 1983 cited in Orde, 1997, p. 273). McGee (1979), also agreed that spatial tests might predict spatial ability, which are used "for selecting workers for industrial jobs and predicting job performance and ...for the prediction of success in vocational-technical training programs"... "The U.S. Employment Service (1957) has listed those occupations

requiring a high level of spatial ability. Four job categories- engineering, science, drafting, and designing- account for nearly 85% of all jobs listed" (p. 894). Even the government recognized the predictive validity of occupational aptitude tests involving spatial ability. Today, the use of tests to predict success in school is a widely accepted practice such as classroom tests designed by the teacher and standardized tests (SATs and ACTs).

Although this study did not find a correlation between math and MRT performance, "In a study of adolescent right-handers, Pezaris and Casey (1990), found high math/science achievers outperformed low math/science achievers on the Mental Rotations Test" (Moody, 1998, p. 18). Many studies examined the influence of math ability and performance on the MRT. McGee's (1979), study found several validity studies where there was a positive correlation between scores on spatial ability tests and mathematical ability (Hills, 1957; Bennett, 1974; Eisenberg and McGinty, 1977).

Visual-Spatial Abilities. This study agreed with Baker (1990), on the importance of nonacademic experiences (visual-spatial activities) performed in the past for predicting MRT scores. Baker (1990), believed men may have scored higher than women on the MRT because they performed these activities (i.e. playing with Lego blocks) when growing up significantly more than females.

This study and other studies disagreed with the findings by Peters et. al (1995). Peters et. al (1995), did include some of the same visual-spatial activities as this study, such as playing with Lego blocks and video games, to understand how they affected MRT performance. Their results found that although males indicated that they played with Lego blocks more often than females when they were children, there was no relationship between playing with Lego blocks and performance on the MRT with men, but with women there was a slight correlation (Peters et al.,

1995). They also found that males played more video games than females, but there was no correlation between playing with computer games and scores on the MRT for either sex.

Several other studies have been conducted to determine the type of visual-spatial activities in which high spatializers have participated. They found that activities requiring hand-eye coordination may have helped develop spatial skills, such as "playing with construction toys as a child, taking classes such as shop, drafting, or mechanics in school, playing three-dimensional computer games, playing in sports, and having good math skills" (Medina et al., 1998; Deno, 1995; Leopold et al., 1996 in Sorby, 1999, p. 24). *Section 2* of the questionnaire in this study was designed from these studies to provide a more well-rounded profile of a high spatializer. It included the following items: erector sets, building blocks, Lego blocks, puzzles, other building toys, video games, model-making, art museum visits, art classes, and sports/physical activities. One reason why the results of this study found a significant, positive correlation between past visual-spatial activities and MRT performance may be because the questionnaire included many spatial enriched activities. This agreed with Baker (1990), who found that high spatializers experienced more spatially enriching activities, both inside and outside the classroom, which may have helped them do well on the cognitive tests. Both of these studies may suggest that a person may have an early aptitude or interest in working in three-dimensional activities.

Mental Rotation Strategy. There are two opposing views of how the MRT scores were correlated to the mental rotation strategy to solve the problems (*Section 3,* question 1, the Use of Mental Rotation Strategy of the questionnaire). Barratt (1953), found that participants who rotated a section of the figure as opposed to the whole figure scored significantly higher on the MRT (Barratt, 1953 cited in Moody, 1998, p. 14). Conversely, Peters et al. (1995), found males who rotated parts of the figure scored significantly worse than males who stated that they rotated the entire figure (p. 46). This study

agreed with the findings of Peters et al. (1995), but it did not study the mental rotation strategy within each gender. In this study, students who rotated the whole figure scored significantly higher on the MRT than students who rotated a section of the figure, and a high percentage of males as well as females stated they mentally rotated the whole figure as opposed to mentally rotating a section of the figure.

Verbal and Visual Strategy. This study partially agreed with researchers on the Verbal and Visual Strategies to solve the problems on the MRT (*Section 3,* question 2 of the questionnaire). This study agreed that "Participants who used the abstract (mental pictures) [nonverbal] approach scored higher than participants who used the concrete (verbal) approach" (Barratt, 1953 cited in Moody, 1998, p. 14). Yet, Peters et al. (1995), found more males than females used a nonverbal strategy, and Moody (1995), found that "men and women differed significantly only in the verbal/visual strategy used with 50% of men indicating they used a visual strategy and 30.9% of women indicating they used a visual strategy ($p=.03$)" (p. 46). This study does not agree with these findings; for males and females the visual approach was significantly more dominant than the verbal approach, however, the visual approach was stronger for males.

Use of Body Movements Strategy. This study did agree with past studies on the use of body movements strategy to solve the problems on the MRT *Section 3,* question 3 of the questionnaire. Although a majority of both males and females did not use movements of their fingers, hand, and/or pencil to help solve the problems on the MRT, a significantly higher percentage of females more than males did report using movements of their fingers, hand, and/or pencil to help solve the problems on the MRT. "Men reported using their hands significantly less, counting blocks significantly less, and picturing in their minds significantly more than

women" (Freedman and Rovegno, 1981 cited in Moody, 1998, p. 16; Peters et al., 1995; Moody, 1998).

Time Limit of the Test. There are two opposing views on why women received lower scores on the MRT. Goldstein, Haldane, and Mitchell (1990), found that when the time limit on the test was removed the sex difference on the MRT was no longer significant (in Moody, 1998, p. 16). Conversely, Resnick, (1993), discovered that sex differences still occurred with untimed conditions, stating "The differences in Mental Rotations Test scores between men and women are not merely the result of women using a slower problem-solving strategy" (cited in Moody, 1998, p. 16).

RELATIONSHIP TO ORIGINAL PROBLEM/QUESTION

Has this study resolved the question: Is the mental rotation performance of high school students in art and non-art classes on Vandenberg's Mental Rotations test affected by art ability, gender, academic performance, visual-spatial activities, strategies used while performing the test, and the ease of taking the test? The answer is yes and no. Yes, mental rotation performance was affected by gender, visual-spatial activities performed in the past, mental rotation strategy and visual and verbal strategy used while performing the test, and ease of taking the test. No, mental rotation performance was not affected by art ability, body movement strategy, visual-spatial activities performed in the present, or on what students reported as their best academic subject.

CONCLUSIONS AND RECOMMENDATIONS

PRACTICAL CONCLUSIONS

On the practical front, this study points to the need to have a spatial ability syllabus integrated into the academic curriculum, especially math, science, and art programs. However,

students have dissimilar learning styles and integrate information differently at various ages. Therefore, an age appropriate spatial training program is needed at each grade level. It should begin possibly at an early age, such as in elementary school when children, especially girls, "are at the concrete operational stage in grades 2-6 ... [and] activities with Dienes blocks and Cuisenaire rods in math classes" are performed (Baker, 1990, p. 36). In support of Gardner's Theory of Multiple Intelligences (Gardner, 1993), students who are not academically strong may improve their grades because they have approached learning from a different modality. These skills are important because "Spatial abilities have been widely studied and are known to be fundamental to higher-level thinking, reasoning, and creative processes... Research on mental imagery has shown that several of the component skills can be improved by training" (Holliday-Darr, Blasko, and Dwyer, 2000, p. 4; Orde, 1997).). Perhaps, if students are given the MRT after having spatial ability instruction throughout their primary and secondary education, females may not score lower than males on the MRT.

If educators, including art teachers, could know which students have spatial ability, they would have insight into these strengths and weaknesses of their students. They can encourage them to increase this ability through instruction. If students do not have strong spatial skills, teachers may alter their curriculum to develop them. When learners have strong spatial skills, training may strengthen them. Moreover, if students know the level of their spatial ability, it may give the ones with poor spatial ability the impetus to improve these skills. This would give them the opportunity to go into careers they never thought possible, such as fields related to science, math, or engineering. Improving spatial skills may augment their higher-level education.

Many studies have been conducted with all ages, where spatial ability training may have been beneficial. Seddon and Shubber (1985), found that 13-17 year olds could improve their spatial ability with instruction, although it increased with age. They also found in their pretest there was no significant difference in the scores on spatial tests in the age groups 15-16 and 17-18 (grades 9-12), which is consistent with the findings of this study. Yet, 13-14 year olds did much worse than the 15-18 year olds on the pretest and the posttest, possibly because of -- developmental issues.

In devising a spatial ability curriculum, much thought needs to be done to assess the types of skills students may need and create a program geared towards learning these skills. When designing spatial oriented programs, certain types of hands-on experiences at an early age should be strongly considered. Much of science, math, and art can be taught using three-dimensional materials and aids, but it should be done at all grade levels.

Art should be more seriously considered as a tool to make this happen. There are many three-dimensional art projects that can be integrated with math and science. Multi-modal instruction would enable students to have a better understanding of the academic material. Projects not only bring content to life, give it validity, but it also reinforces spatial ability and its importance in other disciplines. For example, if students are studying the laws of motion in physics, they could study and create mobiles, modeling Calder's style, which requires balance, weight, and proportion of the individual pieces to balance the sculpture visually and physically. Hopefully, research on the need for spatial ability skills will force the educational system to begin viewing spatial ability skills as important as reading and writing skills. All three of these skills combined may bring to the work force a more productive, creative thinker.

THEORETICAL IMPLICATIONS

On the theoretical front, ideally more true experimental studies are needed in which randomly selected subjects of various ages are tested on specific spatial skills and strategies. Also, in true experimental studies randomly selected and randomly assigned subjects of all ages should be exposed to spatial training. This would allow researchers to have precise data on the different kinds and levels of spatial ability in all age groups and hopefully understand the internal and external influences affecting the present, innate ability level in a person and devise a basic, longitudinal spatial training program to study and develop these skills.

Ozer (1987), conducted a longitudinal study on ages 3-18 in order understand the gender differences on spatial visualization. His results concluded that the "causes of individual differences in spatial visualization are also different for the two sexes. Rather than ask what causes the sex difference in spatial visualization and what underlies the different correlates in each sex, it may be more fruitful to seek the origins of individual differences of this ability in males and females and to expect to find answers in different places" (p. 134). So in devising a spatial training program, more research should be done as to how each gender processes visual information.

GENERAL CONCLUSIONS

This study examined only one area of spatial ability, mental rotation, using one well-documented data instrument, the MRT, and one self-designed instrument, a questionnaire. In order to get a complete view of spatial ability, the other components should be studied as well, such as spatial visualization and spatial orientation.

In order to develop a profile of a high spatializer, future longitudinal studies should contain a battery of these age-appropriate tests and questionnaires, which contain information about participants' visual-spatial activities. Unfortunately, time, the available population, and the

inability to purchase other tests limited the scope of this study. Nevertheless, the data gathered here does support some of the findings of past research on the MRT: gender differences, visual-spatial activities students performed in their past, and strategies they used while performing the MRT. It also included more information than past research: the ease of taking the test and provided a more rounded profile of a high spatializer.

This study is important because it validates past research, but with a population of high school students, who are at a crucial, impressionable time in their lives. Children at this developmental stage are crossing over from childhood to adulthood, where outside influences may affect their development and the career choice they may select. The more they know about themselves the more they may be able to make these vital decisions; this includes knowing their level of spatial ability.

If "spatial skills are viewed as a purely innate ability then any person who has been told that they have poor spatial skills will be likely to avoid activities and courses that might actually improve those skills" (Holliday-Darr, Blasko, and Dwyer, 2000, p. 5). This happens in cultures such as the United States. If "a training program that demonstrates to a student that spatial skills CAN be improved [it] should have an attitudinal impact that goes beyond basic skill improvement" (Holliday-Darr, Blasko, and Dwyer, 2000, p. 5).

There are studies that may have been successful on testing and training elementary through high school students and college students, but more research needs to be done to take this information and develop a spatial ability curriculum across all grade levels to strengthen all types of spatial skills, including both spatial visualization and spatial orientation. This may expose students to areas of study, which never would have occurred to them or they never would have

tried to do, such as careers requiring visual imagery: visual arts, science, engineering, architecture, design, and other related fields.

A few questions may be asked about this study. If this study had a more diverse population, would the results have been different? Also, it may be interesting to test high school students in math and science honor classes, and compare the results to the results of past studies. Are the MRT scores of math and science honor classes affected by art ability, gender difference, visual-spatial abilities performed in the past, and strategies used while performing the test? Possibly a future study should compare a students' three-dimensional artwork to their scores on the mental rotation test; would these students with high test scores be gifted in creating three-dimensional art?

More exploratory research would be to test subjects on two-dimensional and three-dimensional abilities simultaneously, using appropriate tests for each. Is there a correlation between these two abilities? Why are people stronger in one and weaker in the other, or are they at the same level in each? This information would be beneficial to art teachers because they could provide instruction to students immediately, since they may be able to assess their students' strengths and weaknesses through these tests. The ultimate goal of this area of research would be to have a visual-spatial curriculum that that would test and instruct both areas of spatial ability, spatial visualization, and spatial orientation in order to guide students to reach their potential and live enriching, productive lives. This type of curriculum may be a way to reach all students, not just those who do well in academic subjects.

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APPENDIX: PILOT STUDY

In the pilot study the MRT was scored using the *scoring by item* method, one point was given each correct answer with a total of 40 possible points.

Table 2 below shows the results, the raw scores of the pilot study. Males scored higher than females, which supports *Hypothesis* 3.

Table 12: Raw scores of the pilot test, X_b= high school boy (n=5), X_g= high school girl (n=2);

Raw Score out of 40 points	
X_b	X_g
40	23
39	21
38	
34	
32	

Purposive sampling formed a sample of high school students [n=7: males (n= 5) and females (n= 2)] from the same high school as this study. They were the researcher's son's friends. It was conducted to determine if the MRT and questionnaire were valid, reliable, and appropriate for the grade levels being tested. The procedures for the pilot study were mentioned above. The administration of how they were done is given below. Reliability and validity results and data analysis are shown in the Appendix. After the pilot study was conducted, the researcher received verbal approval from the principal and the teachers to set up dates to test their students.

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